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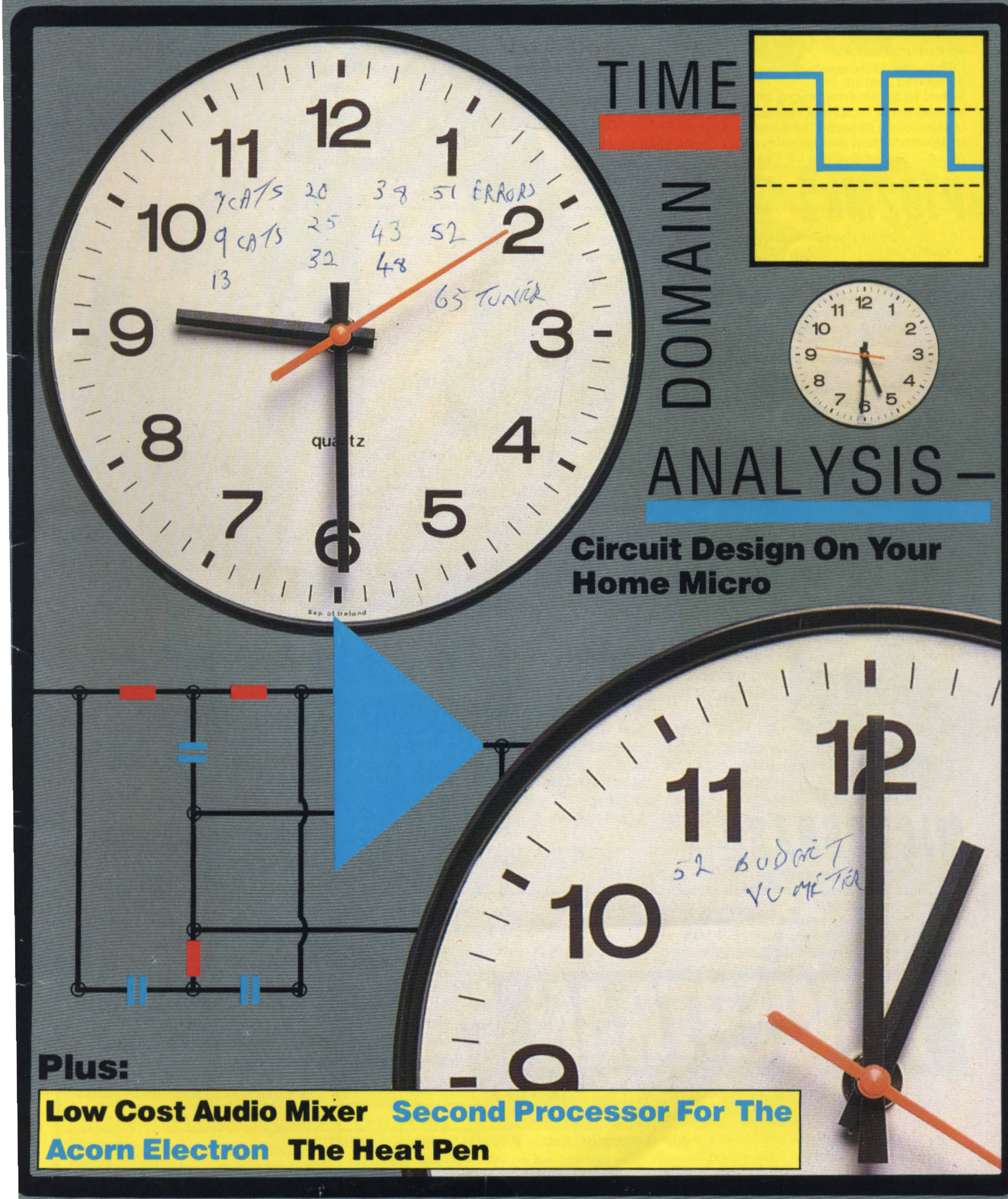

TIME DOMAIN ANALYSIS — Circuit Design On Your Home Micro

Plus:

Low Cost Audio Mixer · Second Processor For The Acorn Electron · The Heat Pen

AUDIO.... COMPUTING.... MUSIC.... RADIO.... ROBOTICS....

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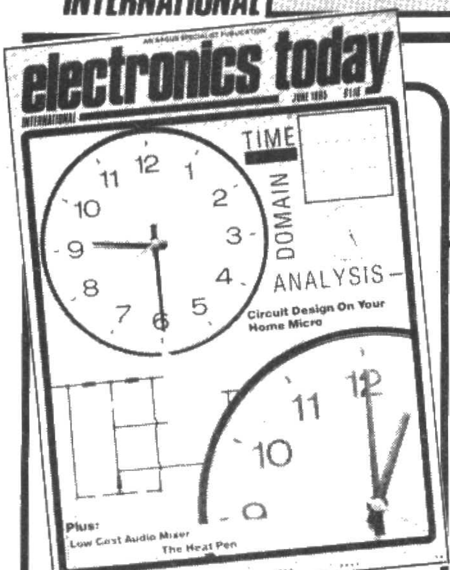

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FEATURES

PROJECTS

ETC

INFORMATION

DIGEST

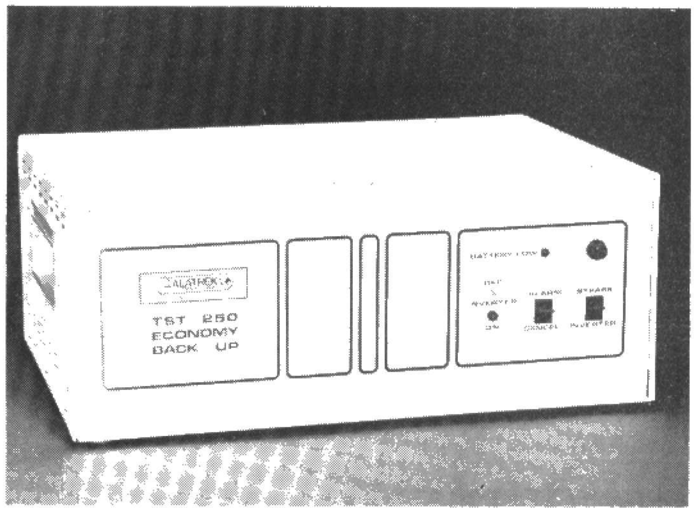
New Single-Chip Micro-computers

Hitachi have developed two 8-bit, CMOS, single-chip micro-computers. They are intended for use in low-end control applications and one includes integral EPROM to facilitate product development and low-volume production.

The HD6305V and HD63705V are available in 1.0, 1.5 and 2.0 MHz versions and have identical functions except that the HD63705V incorporates 4K of on-chip EPROM. They feature 4K of ROM, 192 bytes of RAM, 31 input/output ports and are compatible with the HD6305 family. Other features include an 8-bit timer with a 7-bit pre-scaler, a 15-bit timer which can also be used as a clock divider for serial communications interfacing and a synchronous serial communications interface. Typical power consumptions are 25mW in operation, 10mW in WAIT mode and 10uW in STOP And STANDBY modes. They are available in JEDEC-standard 40-pin DIL packags or in 54-pin flat packages.

The HD63705V has a window for ultra-violet erasing and uses 12.5V for programming. Hitachi expect it to find applications in development and initial production, allowing early samples of equipment to be produced without waiting for the permanent ROM to be prepared.

The HD6305V is available now and the HD63705V should be available from May.



Uninterruptible Power Supply For Microcomputers

Galatrek have introduced a range of low cost Uninterruptible Power Supply (UPS) units which have been specially designed for the smaller and multiple micro-computer user at a price in proportion to the hardware. Three versions are available for 120, 250 and 500 VA outputs, and the prices start at £531.00.

The TST Range of UPS units can handle input voltage swings of +/- 15% and still maintain a stablilised, transient free output voltage, held within +/-5% on combined line and load variations. The wave form distortion is less than 5% and back-up power from the integral maintenance-free, lead acid batteries is normally a 20 minute cycle. However, simply by adding extra battery packs, the cycle can be extended to 24 hours and more if required.

The series offers complete user flexibility which includes extending the frequency of the standard models from 50 HZ to 60 Hz or changing the 220/230 and 240 voltage of the standard range to 110 volts. A further special version is available which has an input voltage window variation in the range +15% to -30%.

The controls include a cancel switch for mains faulure alarm and a manual by-pass switch for coping with high start-up loads. The battery discharge condition is indicated by an audible alarm and visual display which operates two minutes prior to discharge condition and shutdown.

Galatrek International Ltd, Scotland Street, Llanrwst, Gwynedd, North Wales LL26 OAL, tel: 0492-640311.

Just When You Thought It Was Safe To Open The Magazine Again . . .

ETI presents another in its series of cut-out-and-throw-away horror pics for the serious collector. Pictured above after yet another attempt to tidy his desk is former ETI editor Dave Bradshaw. Thankfully, Dave is still with us having been promoted to Group Editor. And the desk? Well, that's still around too and looking a lot tidier these days.

● Weald Electronics produce a range of specialist connectors which includes the BA, D2, SM, SMA, SMC and SREC series, along with the necessary assembly tools. The range is described in a sixteen page A4 illustrated catalogue which is available from their UK distributors, F.C. Lane (Components) Ltd, Slinfold Lodge, Horsham, West Sussex RH13 7RN, tel 0403-790200.

○ As from May of this year, the Health and Safety Executive will be making their database available to computer users in hour-long links via the services of Pergamon Infoline. The database contains information on industrial noise regulations, handling of hazardous substances and over 6,000 other factors relating to work-place health and safety and the link-up is free. For details contact Pergamon Infoline Ltd, 12 Vandy Street, London EC2A 2DE, tel 01-377 4050.

● Canford Audio supply a wide range of mail order audio equipment, from tape recorders, mixers and amplifiers down to audio connectors, audio modules, rack-mounting and other cases, audio transformers, linear faders and cables. Their 72 page catalogue is available from the head office, Canford Audio Ltd, Stargate Works, Ryton, Tyne & Wear NE40 3EX, tel 091-413 7171.

● International Rectifier have brought out a new edition of their power semiconductor product guide and data book. It includes a JEDEC/alpha-numeric index and covers thyristors, rectifiers and Schottky devices of up to 300A rating. Contact International Rectifier, Hurst Green, Oxted, Surrey RH8 9BB, tel 988-3215.

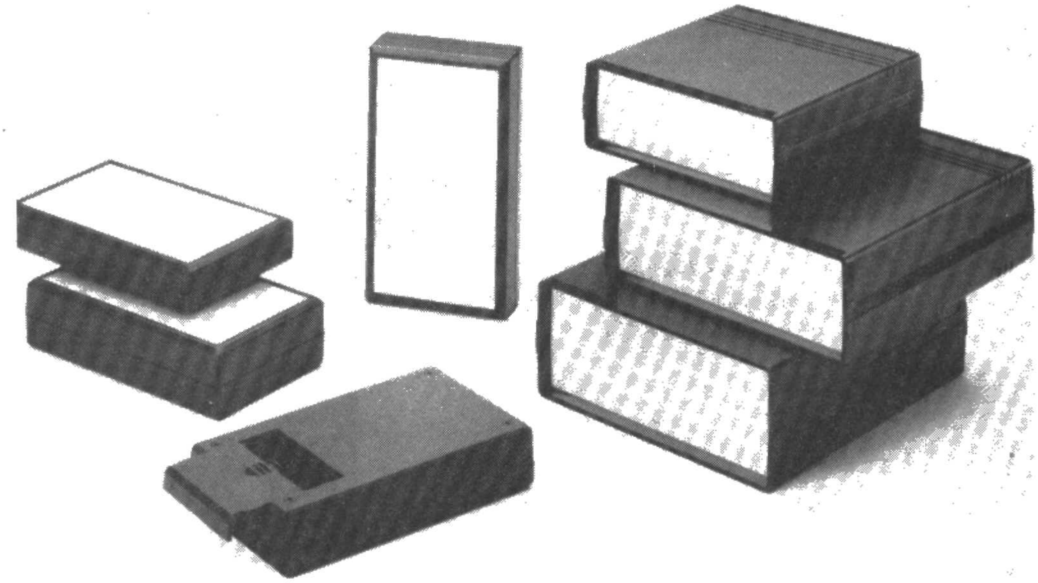
● Yes, Prime have moved to the middle of Nowhere (popularly known as Milton Keynes). The latest in a long line of companies who have decided to set up in the Land of the Concrete Cows, Prime will be spending £6 million on a new research and development centre which will bring 200 jobs to the city when it opens in 1988.

● Marathon Batteries Ltd have produced a small colour brochure describing their range of rechargeable nickel-cadmium cells. The capacities available range from 0.1 to 7 ampere hours and the brochure gives full details of their technical characteristics, construction and charge/discharge performance. For a free copy contact John Rich at Marathon Batteries Ltd, Union Street, Redditch, Worcestershire B98 7BW, tel 0527-62351.

● The Data Protection Registrar has published a 36 page, A5 booklet which provides an introduction and guide to the workings of the 1984 Data Protection Act. The first of a series of guidelines, it is intended to help those covered by the Act to assess its implications. Copies are available from the Office of the Data Protection Registrar, Springfield House, Water Lane, Wilmslow, Cheshire SK9 5AX, tel 0625-535777.

● Citec Ltd have produced a brochure which outlines the potential uses of cermet and polymer thick film technologies. It describes some of the work of the company in applying these technologies to a diverse range of problems, and copies can be obtained from the Product Manager, Special Products Group, BICC-Citetc Ltd, Cheney Manor, Swindon, Wiltshire SN2 2PZ, tel 0793-487301.

● Over half of the workforce of Factron Schlumberger are giving up a day's holiday entitlement in aid of Ethiopia. The company, which makes test equipment and information management systems, employs over 400 staff at its headquarters in Dorset and the £5,000 raised will be used by Oxfam in Ethiopia, Sudan and Mali.



A, A, What's going in 'Ere Then?

West Hyde Developments have added two new designs to their range of small cases, one intended for hand-held application and the other for portable or bench-top equipment. The hand-held case incorporates a compartment for AA or PP3 batteries.

The Novara case comes in three sizes, all designed to fit comfortably into the hand. It is moulded from black ABS in two halves held together with self-tapping screws, and has an aluminium front panel recessed into the moulding. The two larger sizes are available with an optional battery compartment which accepts either one PP3 battery or two AA cells.

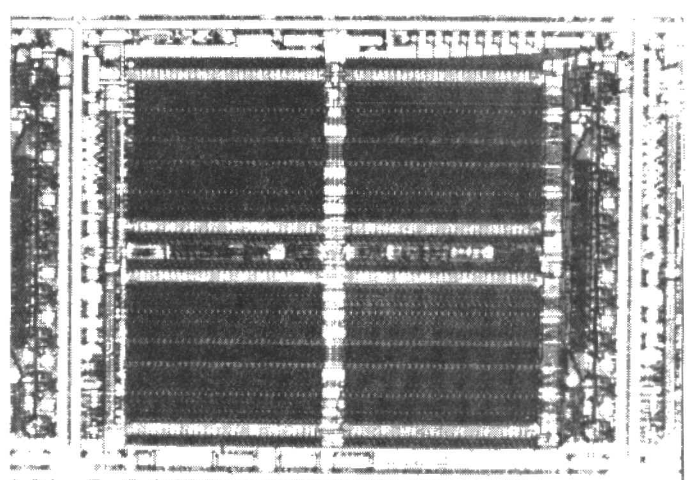
The smallest Novara case measures 145 x 85 x 25mm and costs £5.98, the next size up measures 145 x 85 x 31mm and costs £6.80 or £6.96 with the optional battery comparment, and the largest size measures 145 x 85 x 37 and costs £7.61 or £7.78 with a battery compartment. All prices exclude VAT.

The bench-top case is called the Verona and is available in six sizes. It is moulded from either black or grey ABS in two halves which incorporate bosses to support a board or chassis as well as slots to support PCBs vertically. The front and back panels are of aluminium and slot into recessed grooves.

The Verona comes in two standard width/depth combinations, each of which is available in three heights. The smaller sizes measure 134 x 129mm and are either 47, 54 or 61 mm high, while the larger sizes measure 173 x 154mm and come in the same range of heights. Prices range from £3.60 to £6.22, excluding VAT.

West Hyde Developments Ltd, Unit 9, Park Street Industrial Estate, Aylesbury, Buckinghamshire HP20 1ET, tel 0296-20441.

Fast 8-Bit A/D Converter



Siemens have introduced an eight-bit analogue-to-digital converter which has a conversion time of just 10ns. The new IC will allow full 8-bit conversion at 100MHz, a task which previously required four ICs and used twice as much power.

The SDA 8010 replaces the earlier six-bit SDA 5200 and dissipates just one watt, compared with two watts for four SDA 5200s to achieve the same speed and word length. A complementary digital-to-analogue converter designated the SDA 8005 is also available and is a mirror image of the SDA 8010. The SDA 8005 can operate at up to 150MHz and both devices are compatible with ECL (emitter coupled logic). The SDA 8010 comes in a 24-pin DIL ceramic package.

Siemens suggest applications for the new ICs in instrumentation, image processing and medical equipment including digital oscilloscopes, transient recorders, diagnostic equipment, radar equipment and high resolution graphic systems. Siemens Ltd, Siemens House, Windmill Road, Sunbury-on-Thames, Middlesex TW16 7HS, tel 09327-85691.

Events Diary

Surface Mounting Techniques & Packaging — May 9th
London west Hotel, West Brompton, London. Seminar organised by Hitachi on all aspects of surface mounting techniques and including question and answer session. Begins with lunch at 1.00 pm and runs until 5.15 pm. Cost is £25.00 inclusive. Contact Julie Richardson on 01-861 1414.

Unix Training Course — May 14/15th
Plessey Microsystems Training Centre, Towcester. Training in Unix system III or V, including hands-on experience using a Plessey System 68. Aimed at data managers and software staff interested in multi-user computer techniques. Contact Plessey Microsystems, Sales Office, Water lane, Towcester, Northamptonshire NN12 7JN, tel 0327 50312.

New IEE Wiring Regulations — May 14-16th
Production Engineering Research Association, Melton Mowbray. Three-day non-residential course on the 15th edition of the IEE Regulations. Cost is £300.00 plus VAT with reductions for participants from companies who are members of PERA. Contact the Booking Bureau, PERA Training, Melton Mowbray, Leicestershire LE13 0PB, tel 0664 64133.

Scottish Electronics Production Show — May 14-16th
Anderston Centre, Glasgow. Exhibition of the latest semiconductor and PCB production equipment, assembly equipment, inspection and test systems, interconnection systems, chemicals and laminates. Contact Cahners Exhibitions Ltd, Chatsworth House, 59 London Road, Twickenham TW1 3SZ, tel 01-891 5051.

Automated Manufacturing Exhibition & Conference — May 14-17th
NEC, Birmingham. Exhibition of industrial robotics and automated manufacturing systems. Contact Cahners Exhibitions Ltd, Chatsworth House, 59 London Road, Twickenham TW1 3SZ, tel 01-891 5051.

Power '85 — May 21-23rd
Metropole Hotel, Brighton. See February issue for details or phone 01-437 4127.

Gallium Arsenide Integrated Circuits — June 3rd
Royal Lancaster Hotel, London. Seminar covering gallium arsenide technology, circuit design and applications. Cost is £145.00 plus VAT and includes lunch, etc. Contact Miss Louise Marriott, Oyez Scientific and Technical Services Ltd, 3rd Floor, Bath House, 56 Holborn Viaduct, London EC1A 2EX, tel 01-236 4080.

Phone '85 — June 4-6th
Kensington Exhibition Centre, London. See February issue for details or phone 0280 815226.

Unix Training Course — June 11-12th
Plessey Microsystems Training Centre, Towcester. See above for details.

European Unix User Show — June 12-14th
Olympia 2, London. an exhibition designed to focus attention on the Unix system and attended by over 120 leading suppliers of Unix software, hardware, systems, peripherals and services. Contact EMAP International Exhibitions Ltd, Durrant House, 8 Herbal Hill, London EC1R 5JB, tel 01-837 3699.

Computers In Manufacturing Show — June 24-27th
Olympia 2, London. Exhibition and conference which aims to cover the use of computers in design, production engineering and manufacturing. Contact Independent Exhibitions Ltd, 154 Heath Road, Twickenham, Middlesex TW1 4BN, tel 01-891 3426.

Condition Monitoring In Hostile Environments — June 26th
Regent Crest Hotel, London. Seminar organised by ERA Technology and COMRAD which covers equipment monitoring techniques aimed at predicting failure and thus reducing downtime. Contact Terri Ecclestone, Seminar Organiser, ERA Technology Ltd, Cleeve Road, Leatherhead, Surrey KT22 7SA, tel 0372 374151.

Leeds Electronics Show — July 3-5th
University of Leeds. The show is in its 22nd year and hopes to have 223 stands on display. Contact Evan Steadman Services Ltd, The Hub, Emson Close, Saffron Walden, Essex CB10 1HL, tel 0799 26699.

Readers' Survey Draw Results

At long last we have finished sifting through the several thousand completed Readers' Survey forms we received. A statistical analysis is being prepared and we plan to spend some time in the near future going through your comments and suggestions. We hope to present some of the results of all this effort in a short article in a forthcoming issue.

Meanwhile there is the matter of the free subscriptions we promised to the authors of the first ten survey forms drawn from a hat. We couldn't find a hat large enough, so with the forms securely placed in a cardboard box we carried out this important ceremony with due pomp and what little dignity we could muster.

Our handsome Classified Sales Executive Caroline Faulkner groped diligently around in the box until she could no longer avoid removing some of its contents while her lovely assistant, ETI Editor Gary herman (38-40-45") shook the box in an unhelpful manner. Assistant Editor Ian Pitt tried vainly to pretend to passers by that all this had nothing whatsoever to do with him while several hangers-on leapt around crying "lights, action," and so forth. The ceremony reached its climax with a brief competition to see who could throw most forms in the air whilst doing the splits.

Somewhere in the midst of all this, ten forms were separated from the mass and passed to the subscriptions department where, with tears in their eyes, staff signed the necessary cash slips. The ten luck winners are:

A. Armstrong, 12 Grays Walk, Bishopmill, Elgin, Morayshire; L.C. Boothman, 35 Spalding Road, Fens Estate, Hartlepool, Cleveland; E. Habets, Gosperstreet, 47/4700 Eupen, Belgium; G. Hodgson, 2 Marlborough Avenue, High Harrington, Workington, Cumbria; M. Jones, 26 Whitchurch Avenue, Broadstone, Dorset; B.L. Marshall, 3 Blandford Road, Chilwell, Nottingham; A.J. Wills, 28 Cedar Drive, Kingsclere, Newbury, Berkshire; A. Woodroffe, 'Ranworth', The Glebe, Felbridge, East Grinstead, West Sussex; M. Woodward, 75 Nelson Road, Aston, Perry Barr, Birmingham; and J. LePirie, 72, City Way, Rochester, Kent.

These readers will all receive one year's free subscription beginning with this issue. Our commiserations to those who were not lucky enough to be picked but we will leave them with the thought that ETI is almost as enjoyable when paid for as when obtained free-of-charge.

● *Rental Electronics have brought out their 1985 catalogue of electronic test equipment available on hire. The range extends from basic items through to the more exotic digital 'scopes, spectrum analysers, etc and even includes CAD/CAM/CAE equipment and 32-bit scientific computers. Rental Electronics Ltd, 7 Arkwright Road, Reading, Berkshire RG2 0LU, tel 0734-876377.*

● Barry Porter's audio designs for ETI always prove popular but most constructors have difficulty getting hold of the radial non-polarised electrolytic capacitors he specifies. N.P. Electronics tell us that they stock a full range of Roederstein EKU non-polarised electrolytics and can offer kits of these components for Barry's recent designs at favourable rates. Contact them at The Mill House, Watlington, Kings Lynn, Norfolk PE38 9DW, tel 0553-810096.

● Voluntary Service Overseas are looking for six people who hold a full City and Guilds, TEC, or other equivalent qualification to work in the Third World for two years. The posts are in Egypt, Sri Lanka, Belize, Kenya and on the Maldive Islands and mostly involve teaching electronics or training others to maintain electronic equipment. Applicants should be between 23 and 65 and have British or EEC passports, and if posted will receive local rates of pay and free accommodation. Contact the Enquiries Unit, VSO, 9 Belgrave Square, London SW1X 8PW, tel 01-235 5191.

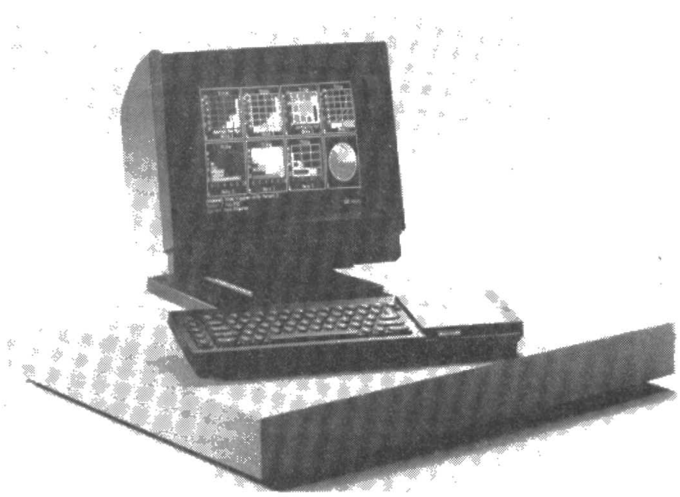
35" Colour Tube And Television

Mitsubishi have developed a colour television tube which measures 35" across the diagonal and is claimed to be the largest in the world. The tube will be used in a new 35" colour television set which will feature audio-visual and RGB inputs.

The tube is said to be the largest direct-view tube ever produced and offers a picture size previously achieved only by projection televisions. Computer simulation was used to optimise the distribution of glass thickness so as to achive minimum weight and facilitate mass production. A deflection angle of 110 degrees has been used which allows a fairly compact overall size to be achieved, and the complete television is 23" (580mm) deep and 36" (910mm) wide.

The screen area of the new tube is 3.1 times as large as that of a standard 20" television and Mitsubishi claim that the picture remains crisp and clean in spite of the large size. The television includes three sets of audio-visual inputs to permit connection of videocassette and videodisc machines and for the reception of satellite broadcasts and there is also an RGB input for teletext and personal computers.

For details contact the Peripheral Products Group, Mitsubishi Electric (UK) Ltd, Hertford Place, Denham Way, Maple Cross, Rickmansworth, Hertfordshire WD3 2BJ, tel 0923-770 000.



QL Monitor From Microvitec

Microvitec have produced a colour monitor which is designed both technically and visually to suit the Sinclair QL microcomputer and which includes a tilt and swivel stand. The monitor is aimed particularly at business users of the QL and is designed to satisfy the demand for a 'workstation' type display.

Microvitec were the first company to produce a colour monitor which was fully compatible with the QL's 85-column width display and also capable of doing full justice to the machine's colour graphics potential. The new monitor retains the same technical specification, including a 653 pixel-per-line CRT and an 18MHz bandwidth. It has a black finish which matches the external appearance of the QL and the integral stand allows it to be angled to provide the most comfortable working position.

The QL-compatible monitor is expected to sell for just under £300.000. For further information contact the Sales Department, Microvitec PLC, Futures Way, Bolling Road, Bradford, West Yorkshire BD4 7TU, tel 0274-390011.

Passing The Backnumbers

Not before time, we have actually got around to clearing up the ETI office a bit. Amongst the rubble we have found a number of past issues of the magazine, mostly from 1983. Our regular backnumber service does not have the space to handle them, and as some are a bit the worse for wear after kicking around in odd corners for so long it seems unfair to expect people to pay the normal £1.50 a time.

Accordingly, we have decided to make them available to readers in return for fifty pence to cover postage, etc. If you want any of the issues listed below, just write to us at the address given on the contents page and enclose a cheque or postal order made out to ASP Ltd. It would also save us time if you would enclose your address either on a gummed label or at least on a piece of ordinary paper which we can then paste down.

By all means order more than one issue if you wish, but please don't enclose any other requests or enquiries; it would only slow things down. We won't be able to write out explanatory notes or anything, so if your cheque or postal order is returned you should assume that we have run out of copies of the issue you asked for.

The issues we have copies of are:-

NOVEMBER 1982; **projects include the first part of the Cortex sixteen-bit computer, a precision pulse generator and a spectrum analyser, and there are features on satellite TV and switched capacitor filters.**

JANUARY 1983; projects include **the first part of the programmable stage lighting unit, the final Cortex article, a programmable bench power supply, a waveform multiplier for synthesisers and an ADC for ZX81s or Spectrums, while the features include a review of the movie Tron and an article on operational amplifiers.**

MARCH 1983; **projects include the second part of the ETI Victory electronic organ, a user-defined graphics board for the ZX81, a 6502 sound board and a logic probe, while the features include a second look at satellite TV in the wake of the Part Report and articles on audio output stage design, broadcast standards and laser diodes.**

APRIL 1983; **projects include the third parts of both the stage lighting unit and the Victory organ, the first part of a ZX81 music board and a real time clock for 6502-based systems, and there are features on both switched mode power supplies and conventional PSUs and articles on voltage multipliers and the use of nested differentiating feedback loops (NDFLs) in audio amplifier design.**

MAY 1983; **projects include the final parts of both the stage lighting unit, the Victory organ and the ZX81 music board, plus an audio compressor/limiter, a stabilised PSU for hi-fi amplifiers and a sixty watt amplifier designed using NDFL principles. The features include an eight-page buyer's guide to hi-fi and an article on four-channel semiconductor devices.**

JUNE 1983; **projects include the first part of a switched mode power supply design, a numerical keypad for the Acorn Atom and an electronic compass, and there are features on opto-electronics, buying test gear, and the fabrication of mechanical structures on silicon chips.**

DECEMBER 1983; **projects include the first part of Barry Porter's modular preamplifier, an EPROM controlled light chaser and a sixteen channel A-to-D board, while the features include articles on tone control design and machine code programming.**

ETI

READ/WRITE

You Are Not Alone

Dear Sir,

1. In the Feb 1985 issue of ETI you make a lame excuse for not completing the long-delayed JLH article on his THD meter. Yet on pages 3, 26 and 29 you take up invaluable space with idiotic and vulgar rubbishy 'cartoons' unworthy of a reputable journal.

2. Your mix is about 10 to 1 in favour of computer items, some of them quite silly, over audio ideas. You must know that on our bookshop shelves there is a 20 to 1 preponderance of computer magazines both in England and South Africa. Why not yield a little more space for audio, particularly the brilliant JLH?

3. I wrote to you recently about Newrad's failure to supply my order for components for the JLH amplifier. A parcel arrived two weeks ago and I found that at least 25% of the items were missing, including the more expensive polycarbonate capacitors. I wrote again and I believe another package is on the way. Please don't use their 'activities' in ETI in the future.

Yours sincerely,
Dr. A.H. Barzilag
South Africa.

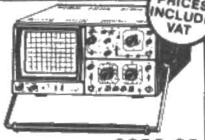
Well, that may be the first time we've been called reputable. We must be slipping. However, to answer your points in turn:

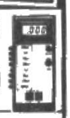
If you saw the March issue, you would realise that the final part of the THD meter project took up four full pages. The cartoons were not an alternative and, in any case, some people actually enjoy such things. Still, we can't please all the people all of the time — as your second point amply demonstrates. ETI's objective is to cover the whole field of electronics.

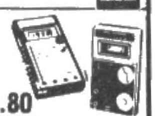
It's a big field and in any one issue we will not necessarily be able to get the mix precisely correct. Your figures don't strike me as accurate, but it is undeniable that there is more interest in computer projects right now than in any other part of the electronics field. We reflect that, partly because the proportions apply to our contributors as much as to our readers. If we received more audio projects, we would probably run more audio projects. We do agree with you about John Linsley Hood, though, and we're quite pleased that his contributions to ETI are both frequent and substantial. Perhaps he likes the magazine more than you.

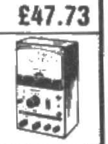
On the final point, we have received a number of complaints about Newrad's delivery of the Linsley Hood MOSFET amp. I've been in touch with the company and they assure me that any problems with the kit are now at an end. The trouble was partly due to necessary alterations in the design and partly to the long lead times for components. Newrad apologise for any inconvenience and ask that you do not phone up with any problems you may have, since this only creates more pressure on time. If you write to them, they will reply — but, they stress, everybody who has ordered a kit will receive a full kit. Delivery times should be acceptable from now on. Naturally, ETI also apologies to any readers who have had trouble with the kit. We can only say that the wait is definitely worth it.

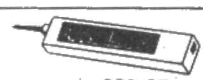
ETI











TIME DOMAIN ANALYSIS

Let your computer do the work after reading Andrew Armstrong's introduction to circuit simulations using BASIC.

There have been complicated and expensive circuit analysis software packages available for some time. Time domain analysis, however, is a simple technique which can be used in BASIC programs on a home computer to analyse circuit performance. The simplicity is due to the fact that analysis is carried out in the time domain rather than the frequency domain.

Frequency domain analysis means calculating the frequency response, and perhaps the phase response, of a linear circuit. The problem is that, even for a very simple-looking circuit, the equations describing the frequency response may be very complicated. Usually, though, the DC behavior of the circuit can be calculated much more easily. What this time domain analysis technique does is to use DC equations for circuit performance, and to apply these equations repetitively at small increments of time. Any required input waveform can be specified as a function, or as a set of data points giving the input voltage at each increment of time.

During each time increment, it is assumed that currents and voltages are constant, while new values for these quantities are calculated. In the first part of the circuit in Fig.1, for example, the charging current of C1 is assumed to be constant during the entire time increment. In reality, the current would decrease steadily as the capacitor charged, so the calculated increase in the charge on the capacitor is greater than the true value. Clearly, the greater the time period, the greater the error. For this reason, a very small time increment is used, and some circuit configurations are analysed using several steps of calculation (ie several time increments) for each point plotted. In effect, time domain analysis involves the integration of equations by numerical approximation. Since they are DC equations, things are relatively simple.

There are a number of circumstances where time domain response is more meaningful than frequency response, of which one obvious example is video. For example, if a low pass filter produces rings and ripples in a square wave signal rather than rounding it off cleanly, those rings will show on the screen - yet the frequency response of the circuit producing the rings may be identical to that of one giving a clean rounding.

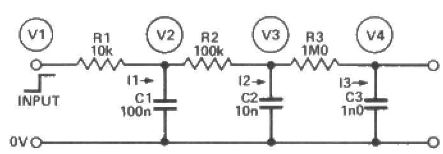
Of course, given that the computer time is available, there is no reason not to carry out frequency response analysis by time domain methods. This transfers the burden of repetitive calculation to the computer rather than the programmer, so that the circuit designer can devote his or her time to thinking about circuit configurations rather than trying to solve equations using complex numbers, which require a piece of paper turned sideways just to write. (And that's only a second order low pass filter!).

DC Analysis

Taking the example of a passive RC low pass filter as in Fig.1, the method of writing the program is, first of all, to write a set of DC equations. These must be chosen so as to be able to be calculated sequentially.

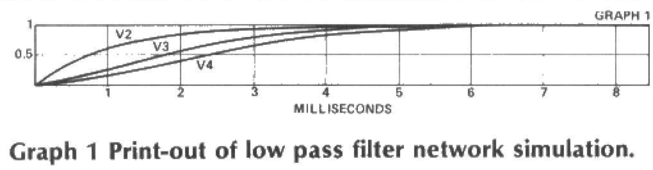
Taking the circuit of Fig.1 as the first example, the equations are:

Fig.1 Low pass filter network.




```
10 '   Analogue circuit analysis program - MAIN PROGRAM
20 '   Andrew Armstrong  06 February 1985
30 '
40 SCREEN 3,0,0:CLS' Select and clear graphics screen
50 '                   Draw grid for graph
60 FOR N 80 TO 430 STEP 50:LINE(N,0)-(N,63),,,43690!:NEXT N'Vertical lines
70 LINE (30,0)-(30,63):LINE (0,63)-(473,63)'                 Draw axes
80 LINE (30,38)-(473,38),,,34952':LINE(30,13)-(473,13),,,61680!'Horiz. lines
90 GOSUB 170
100 FOR N=1 TO 8:M=(30+(N*50))*79/473:LOCATE M,8:PRINT N;:NEXT N'Number scale
110 LOCATE 2,2:PRINT "-1-":LOCATE 2,5:PRINT"0.5"'              Number scale
120 IF INKEY$ <>"1" THEN 120' Do not print "OK" over the graph immediately
130 END
140 '
150 ' Passive (RC) lowpass filter calculation
160 '
170 R1=10000':R2=100000':C1=.0000001
180 C2=1E-08:R3=1E+06:C3=1E-09:DT=.00002
190 FOR N=0 TO 474
200 IF N<30 THEN V1=0 ELSE V1=50
210 I1=(V1-V2)/R1:V2=V2+DT*(I1-I2)/C1'       First node
220 I2=(V2-V3)/R2:V3=V3+DT*(I2-I3)/C2'       Second node
230 I3=(V3-V4)/R3:V4=V4+DT*I3/C3'            Output
240 PSET(N,63-V4):PSET(N,63-V2):PSET(N,63-V3)' Plot output and nodes on graph
250 NEXT N:RETURN
```

Listing 1



Graph 1 Print-out of low pass filter network simulation.

I1 = (V1-V2)/R1
V2 = (I1-I2) * T/C1
and similarly for the second and third parts of the circuit:
I2 = (V2-V3)/R2
V3 = (I2-I3) * T/C2
I4 = (V3-V4)/R3
V4 = (I3-I4) * T/C3

The input waveform, V1, is any arbitrary function which is convenient to generate in software. In this case a simple step is used to demonstrate time delay.

A BASIC program to calculate this is shown in Listing 1, and its print out in Graph 1. The number of steps in the loop is set to be suitable given the response time of the circuit in question. Equally, the value used for V1 is set by the Y scale required, though it would be just as simple to use the value 1 and then scale the answer later on in the program.

The only formulae needed to generate these equations are Ohm's law, and the formula for the change in voltage on a capacitor subjected to a steady current for time T: V = I*T/C. In each small time increment for computing purposes, the current is assumed to be constant, and the change in voltage is added to the previous total. The initial condition used in this program is that all currents and voltages are 0, which is the default condition of the dialect of BASIC in use here.

The shape of the graph showing the response to the input waveform is of interest in that it shows a distinct difference from the exponential charging characteristic of a single R and C. If many stages are added, the result will look like Graph 2 in which a single RC time constant is shown for comparison. In this graph, it is assumed that the current drawn from each RC stage by the succeeding one is negligible, or that they are separated by voltage followers, as in Fig. 2. The effect of ten cascaded time constants is plotted. The routine used is shown in Listing 2.

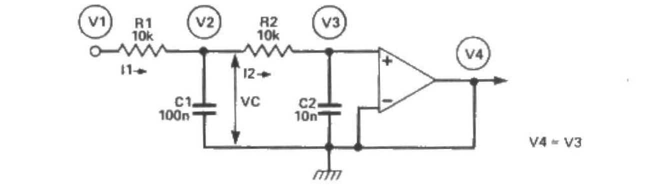
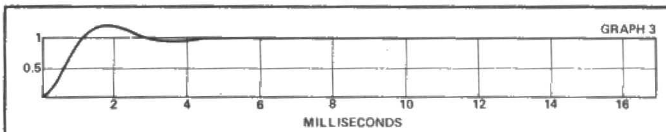


Fig.3 Active low pass filter circuit.

```
10 '  Analogue circuit analysis program - MAIN PROGRAM
20 '  Andrew Armstrong  06 February 1985
30 '
40 SCREEN 3.0.0:CLS' Select and clear graphics screen
50 '                 Draw grid for graph
60 FOR N=80 TO 430 STEP 50:LINE(N.0)-(N.63),,,43690':NEXT N'Vertical lines
70 LINE (30,0)-(30,63):LINE (0,63)-(473,63)'                  Draw axes
80 LINE (30,38)-(473,38),,,34952':LINE(30,13)-(473,13),,,61680''Horiz. lines
90 GOSUB 170
100 FOR N=1 TO 8:M=(30+(N*50))*79/473:LOCATE M,8:PRINT N;:NEXT N'Number scale
110 LOCATE 2.2:PRINT "-1-":LOCATE 2,5:PRINT"0.5"'               Number scale
120 IF INKEY$ <>"1" THEN 120' Do not print "OK" over the graph immediately
130 END
140 '
150 ' Active lowpass filter simulation
160 '
170 R1=10000!:R2=10000!:C1=1.2E-07:C2=2.2E-08:DT=.00001:V1=50
180 FOR N=30 TO 474
190 FOR M=1 TO 4
200 I1=(V1-V2)/R1
210 VC=VC+(I1-I2)*DT/C1:V2=VC+V3
220 I2=(V2-V3)/R2:V3=V3+I2*DT/C2
230 NEXT M
240 PSET (N,63-V3)
250 NEXT N:RETURN
```

Listing 3



Graph 3 Print-out of active low pass filter simulation.

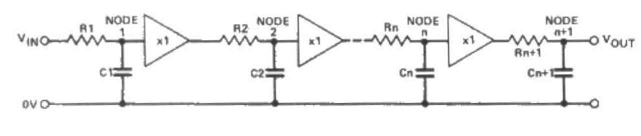
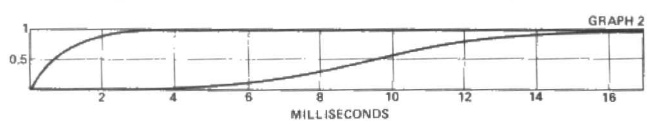


Fig.2 Cascaded time constant circuit.

```
5 DIM V(10)' Array to store node voltages
10 '  Analogue circuit analysis program - MAIN PROGRAM
20 '  Andrew Armstrong  06 February 1985
30 '
40 SCREEN 3,0,0:CLS' Select and clear graphics screen
50 '                 Draw grid for graph
60 FOR N=80 TO 430 STEP 50:LINE(N,0)-(N,63),,,43690':NEXT N'Vertical lines
70 LINE (30,0)-(30,63):LINE (0,63)-(473,63)'                  Draw axes
80 LINE (30,38)-(473,38),,,34952':LINE(30,13)-(473,13),,,61680''Horiz. lines
90 GOSUB 170
100 FOR N=1 TO 8:M=(30+(N*50))*79/473:LOCATE M,8:PRINT N;:NEXT N'Number scale
110 LOCATE 2.2:PRINT "-1-":LOCATE 2,5:PRINT"0.5"'               Number scale
120 IF INKEY$ <>"1" THEN 120' Do not print "OK" over the graph immediately
130 END
140 '
150 ' Cascaded time constant simulation
160 '
170 R1=10000':C1=.0000001:DT=.00001:V(0)=50
190 FOR N=30 TO 474
200 FOR M=1 TO 4'  Extra accuracy loop
210 FOR L=0 TO 9'  Time constant cascading loop
220 I=(V(L)-V(L+1))/R1
230 V(L+1)=V(L+1)+DT*I/C1
240 NEXT L
250 NEXT M
260 PSET(N,63-V(1)):PSET(N,63-V(2))
270 NEXT N
280 RETURN
```

Listing 2



Graph 2 Print-out of cascaded time constant simulation.

Overshoot

The technique can easily be applied to active circuits, such as the low pass filter shown in Fig. 3. The component values for this circuit are chosen so that it is underdamped. This results in an overshoot in the response to a step function, as shown in Graph 3.

Conventional wisdom also has it that there will be a peak in the frequency response, but more of this later. Listing 3 shows the equations used - the first part of the program, which draws the scale, is similar in all cases. Note (line 180) that the loop starts at 30 instead of at 0 as in Listing 1. This eliminates the need for the IF statement (Listing 1, line 200), which was only there to illustrate the application of an input step function.

The inner loop of M (Listing 3, line 190 to line 230) allows the calculation of four points for each one plotted on the graph, so that if high rates of change of any variable occur, a reasonable accuracy can be achieved. The size of this loop may be set as large as necessary to achieve good accuracy, but remember that each step of this inner loop is one time increment, so the step size DT should be scaled down appropriately to obtain the benefit from this. Otherwise, the time scale will simply be compressed, and the accuracy the same.

COMMENTS ON LISTINGS

The computer for which the programs were written, an Epson PX8, has available a graphics screen, on which the individual LCD points may be set. It is numbered from 0,0 in the top left hand corner to 479,63 in the bottom right hand corner. The screen contents can be copied to a suitable printer using the screen dump mode. Once the purpose of the graph plotting statements is understood, there should be little difficulty in performing the nearest equivalent operations on another machine.

As well as being able to set individual points, lines can be drawn. It is almost as fast to draw a line as to set a single point, so this is employed in lines 60, 70, and 80, as shown on Listing 1, to draw the framework of the graph. The line is drawn to the bit pattern of a repeating 16 bit binary number corresponding to the number specified after the three commas in the line statement, the default being a solid line.

Character positions may be specified in x,y co-ordinates, starting with 1,1 on the top left, and finishing with 80,8 on the bottom right. Only whole character positions can be used, but the statement in line 100 LOCATEs the nearest position to the vertical scale lines, which are every 50 pixels for ease of calculation.

To avoid the message "OK" being printed over the graph, the INKEYS function is used in line 120 to keep the program twiddling its thumbs in a loop and allow time to press the screen dump button.

The calculation part of the programs is quite straightforward, and is detailed earlier on.

The only particular point of interest is that a smaller time increment is used in programs 2, 3 and 4 than in programs 1 and 5, and four steps of calculation are carried out for each point plotted. This reduces an otherwise unacceptable cumulative error in the cascading loop in program 2. In programs 3 and 4 the same technique copes with the high rates of change or voltage in the circuits being simulated.

Listing 4 shows the use of an input waveform other than a step at time=0. A sine wave is used, though any definable function may be used. R1 makes writing the equations convenient.

The only limitations on the size of the loop are how long you care to wait for an answer, and how long your computer is liable to be left undisturbed chonking away in peace while you do something else. In practice, I have found that the time taken to eat lunch is a reasonable limit but really fast machines may never need this long. Compiled Basic (or any compiled language) is to be preferred for complicated simulations.

The only significant difference between the active and the passive filter simulation is that the voltage across C1 is measured relative to the op-amp output instead of relative to 0V.

Lumped Constant

The same idea is applied to the voltage across the source resistor in the lumped constant transmission line simulation (Fig. 4, Listing 4 and Graph 4). The resistors chosen are of the nominal impedance of the line, $\sqrt{L/C}$, so the output rings only a little. It is left to the reader to experiment with other values of R1 and R2. 50R gives some entertaining rings!

In principle, this simulation could be applied to almost any linear circuit. If many similar stages were to be simulated, even though they had different values, it would be better to use a loop as in Listing 2, and to refer to component values stored in arrays.

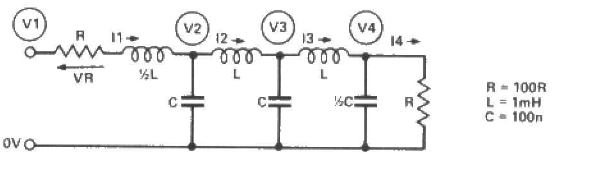
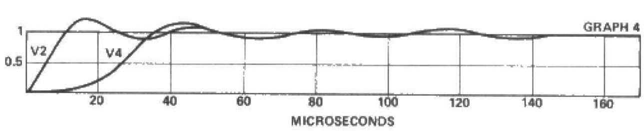


Fig.4 Lumped constant transmission line - equivalent circuit.

```
10 '  Analogue circuit analysis program - MAIN PROGRAM
20 '  Andrew Armstrong  06 February 1985
30 '
40 SCREEN 3.0.0:CLS' Select and clear graphics screen
50 '                 Draw grid for graph
60 FOR N=80 TO 430 STEP 50:LINE(N,0)-(N,63),,,43690':NEXT N'Vertical lines
70 LINE (30.0)-(30,63):LINE (0,63)-(473,63)'                      Draw axes
80 LINE (30.38)-(473,38),,,34952':LINE(30.13)-(473.13)...61680''Horiz. lines
90 GOSUB 170
100 FOR N=1 TO 8:M=(30+(N*50))*79/473:LOCATE M,8:PRINT 20*N.:NEXT N
110 LOCATE 2.2:PRINT "-1-":LOCATE 2.5:PRINT"0.5"'                 Number scale
120 IF INKEY$ <>"1" THEN 120' Do not print "OK" over the graph immediately
130 END
140 '
150 ' Lumped constant transmission line simulation
160 '
170 L=.001:C=.0000001:R1=100:R2=100:DT=.0000001:VI=100
180 FOR N=30 TO 474
190 FOR M=1 TO 4
200 I1=I1+DT*(V1-V2-VR)*2/L:VR=I1*R1:V2=V2+DT*(I1-I2)/C
210 I2=I2+(V2-V3)*DT/L:V3=V3+DT*(I2-I3)/C
220 I3=I3+(V3-V4)*DT/L:V4=V4+DT*(I3-I4)    *2/C:I4=V4/R2
230 NEXT M
240 PSET(N,63-V2):LINE(N.63-V4)-(N,62-V4)'Plot first node and output
250 NEXT N:RETURN
```

Listing 4



Graph 4 Print-out of lumped constant transmission line simulation.

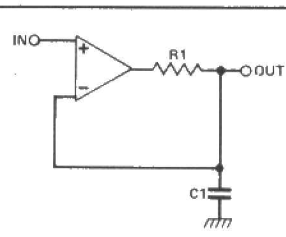
Frequency Response

All the analysis shown so far gives only the time response of a circuit. There are at least two ways in which it can be adapted to provide a plot of frequency response.

The first and most obvious method is to make the input voltage a sinewave, instead of a step function. A large number of cycles is applied to the circuit to allow the circuit to settle, and then the output signal is plotted, or its amplitude measured and the result stored in an array. The frequency is then incremented and the procedure carried out again. It is clear that such a program would take a long time to run, so the writing of code is left as an exercise for the reader.

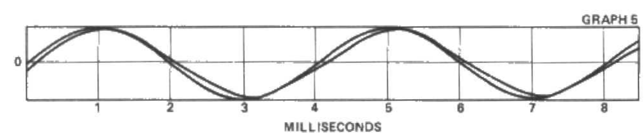
There is another method, still under development, which should turn out more elegant and faster to execute. If the output signal from the circuit were to be spectrum analysed, perhaps by a Fourier transform, and compared with the frequency spectrum of the input, then the frequency transfer function of the simulated circuit could be determined. Phase information would be available as well.

Fig.5 A current limited op-amp configuration.



```
10 '  Analogue circuit analysis program - MAIN PROGRAM
20 '  Andrew Armstrong  06 February 1985
30 '
40 SCREEN 3,0,0:CLS' Select and clear graphics screen
50 '                  Draw grid for graph
60 FOR N=80 TO 430 STEP 50:LINE(N,0)-(N,63),,,43690':NEXT N'Vertical lines
70 LINE (30,0)-(30,63):LINE (30,31)-(473,31)'                 Draw axes
80 GOSUB 160
90 FOR N=1 TO 8:M=(30+(N*50))*79/473:LOCATE M,4:PRINT N;:NEXT N'Number scale
100 LOCATE 2,4:PRINT "-0-"'                                   Number scale
110 IF INKEY$ <>"1" THEN 110' Do not print "OK" over the graph immediately
120 END
130 '
140 ' Current limited op-amp simulation
150 '
160 R1=470:C1=1.8E-07:DT=.00002:ANGLE=ATN(1')/25:GAIN=1000
170 FOR N=30 TO 474
180 V1=30*SIN(ANGLE*(N-30))
190 V0=GAIN*(V1-V2)+V1
200 IF V0>30 THEN V0=30
210 IF V0<-30 THEN V0=-30
220 I1=(V0-V2)/R1:IF I1>.006 THEN I1=.006
230 IF I1<-.006 THEN I1= -.006
240 V2=V2+I1*DT/C1
250 PSET (N,31-V1):PSET (N,31-V2)
260 NEXT N:RETURN
```

Listing 5



Graph 5 Print-out of current limited op-amp simulation.

This technique should work well, because the frequency spectrum of the input step function is continuous, theoretically from zero to infinity (but only if the simulation is for an infinite period!). Any reasonable range of frequencies is liable to be able to be plotted with little difficulty, once the numerical spectrum analysis is working.

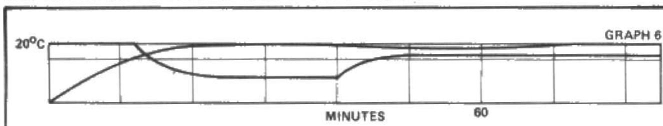
Further Applications

So far, only linear circuits have been considered. It is easy to add the effects of non-linearity anywhere in the circuit by using IF statements. For example, current limiting may be represented by:

IF I>6E-3 THEN I = 6E-3: IF I<-6E-3 THEN I = -6E-3

This limits the current to $\pm$ 6 milliamps, typical of the response of some small op-amps. The effect of a current limited opamp connected in the circuit shown in Fig. 5 is simulated by the program in Listing 5, which feeds a sine-wave into the circuit, and gives the output shown in Graph 5.

This circuit is a first approximation to a model for an op-amp. Equally, a conventional model may be used to simulate a transistor, with sets of values stored in arrays to enable a single transistor simulation subroutine to be used for a multi-transistor circuit.



Graph 6 Print-out of heater control simulation.

The technique can be used for digital and control circuits. For example, Graph 6 shows the effects of PID (proportional, integral, and differential) control using a computer in conjunction with a heating system. In this case, the simulation can be very close to the truth, since the measurements would be sampled and the sampling period of the program can be made identical to that of the system to be used. The thick line on the

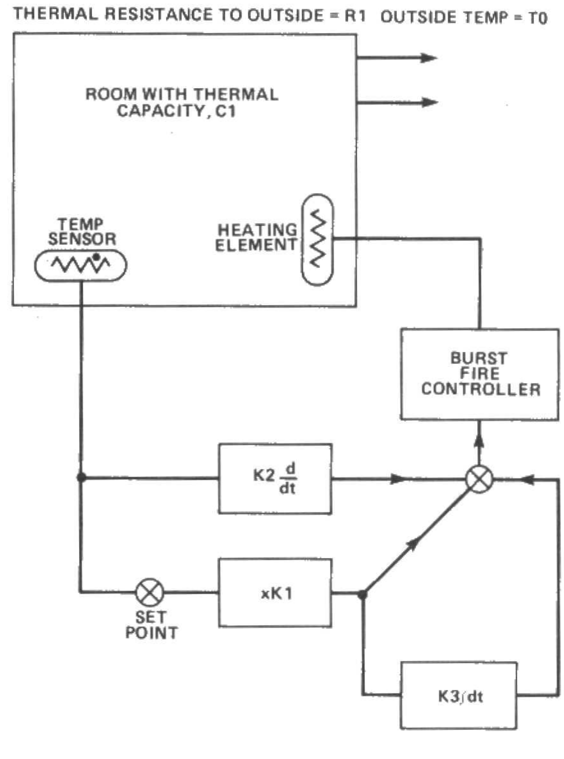


Fig.6 Block diagram of heater control circuitry.

```
10 'Airconditioning simulation program  A. Armstrong 4 Feb. 1985
20 SCREEN 3,0,0:CLS'Select and clear graphics screen
30 '
40 '                Draw grid for graph
50 '
60 FOR N=80 TO 450 STEP 50:LINE(N,0)-(N,63),,,43690':NEXT N'Vertical lines
70 LINE (30,0)-(30,63):LINE (30,63)-(473,63)'              Draw axes
80 LINE(30,13)-(473,13),,,61680!'                          Aiming point
90 GOSUB 130'                        Call calculation routine
100 LOCATE 55,8:PRINT"60";:LOCATE 1,2:PRINT"20^C"'           Scale numbering
110 IF INKEY$ <>"1" THEN 110'TYPE 1 FOR A PRINTED COPY
120 COPY:END'                    THE END OF THE MAIN PROGRAM
130 C1=100:R1=20:T0=0:DAT=2:IAT=15:PB=5:SP=20:DT=.05:HTC=1'Times in minutes
140 X=DT*.36/HTC:Y=1-X'Heater time constant
150 K3=DT/IAT
160 DT=DT*60'convert to seconds
170 BAND=13+(PB*2.5)
180 LINE(30,BAND)-(473,BAND),,,34952'' Draw proportional band lower limit
190 K1=1/PB
200 K2=1/(DAT*DT*PB)
210 ONE = DT'One kilowatt of cooling = 1*time increment
220 FOR N=30 TO 479
230 FOR LOOP=1 TO 4
240 HP=(SP-TEMP)*K1:HD=K2*TD
250 H=HP
260 IF H>1 THEN H=1
270 YI=YI+H*K3'INTEGRATE HEATING DEMAND (WITHOUT INTEGRAL TERM)
280 IF YI<0 THEN YI=0:IF YI>1 THEN YI=1'KEEP INTEGRAL WITHIN LIMITS
290 IF H>.99 THEN YI=0'NO INTEGRATION OUTSIDE LINEAR CONTROL REGION
300 H=HP+YI-HD
310 IF H<0 THEN H=0:IF H>1 THEN H=1
320 IF H>1 THEN H=1
330 TPREV=TEMP
340 HEAT=DT*H*2.5*Y+HEAT*X'THERMAL MASS OF HEATER
350 LOSSES=(TEMP-T0)*DT/R1
360 IF N>229 THEN LOSSES = LOSSES+ONE'ADD 1 KW OF COOLING SUDDENLY
370 TEMP=TEMP+(HEAT-LOSSES)/C1
380 TD=.9*TD+.1*(TEMP-TPREV)'SIMPLE DIGITAL FILTERING ALGORITHM
390 NEXT LOOP
400 TI=2.5*TEMP
410 PSET(N,63-TI)
420 PSET(N,63-50*H):PSET(N,62-50*H)
430 NEXT N:RETURN
```

Listing 6

graph represents heater power, the thin line represents temperature. At time 40 minutes, an extra kilowatt of cooling is introduced (to model, say, a window being opened). The graph shows the effect of such a disturbance to the system.

In this example, the maximum heater power is assumed to be 2.5 kW, the room to outside temperature insulation is 20°C per kW, and the outside temperature is 0 °C. The thermal capacity of the room is assumed to be 100 kilojoules per degree, and the time constant of the heating element is about one minute. **ETI**

THE REAL COMPONENTS

In this, the fourth article in his series, John Linsley Hood looks at transistor parameters and design calculations based upon them.

It is a useful thing to be able to calculate how an electronic circuit will behave, and in the case of valves, this was quite straightforward. Transistors are a different and rather more difficult matter, not helped very much by the fact that there are such a wide variety of terms and symbols used by different manufacturers and text books to describe exactly the same thing.

However, it looks more difficult than it is — at least at low frequencies — to do the sums, and I propose to try and prove this. But first, we must specify the meaning of the terms.

Resistance Well, that is straightforward enough, and just defines that quality in the obstruction of current flow which causes a voltage drop (or potential difference). R=V/I.

Impedance Basically the same thing as resistance, but allowing for the fact that there is some capacitative or inductive component in the resistance to current flow, so that the actual value will be different at different frequencies. Pure resistance is an uncommon thing in real life because most obstructions to current flow are, in truth, impedances, so this is a word which can be used to describe what one means without much risk of contradiction.

Conductance This is the reciprocal of resistance, and is measured in amps per volt (I/V) instead of volts per amp (V/I).

Admittance This is the reciprocal of impedance, and again is given in terms of amps per volt, but at some specific frequency. Both conductance and admittance are expressed in Siemens *(=S)*. *1S*=1amp/volt, 1mS=1mA/V, and so on.

The symbol R is conventionally used to indicate resistance, and Z to indicate impedance. G is used to indicate conductance, and Y for admittance.

When dealing with transistors it is customary to look at them as small 'black boxes' with four terminals. The input circuit is labelled 1 and the output circuit is labelled 2, as shown in Fig. 1a or in the equivalent circuit shown in Fig. 1b.

Conventionally, again, the currents which flow in circuit 1 as a result of the voltages applied to the input terminals are referred to as 11. Those which flow in the output as a result of voltages in the output are referred to as 22 and those which flow in the output as a result of currents in the input are described as 21 and so on.

Originally, the input characteristic was measured as an impedance, Z, giving rise to terms like Z11 to define the input impedance, and the output circuit defined as an admittance, so that the output admittance would be specified as Y22. Nowadays, it is much more common for these to be known as h or 'hybrid' parameters, so that Z11 becomes h11 or h_i, and the output admittance Y22 becomes h22 or h_o.

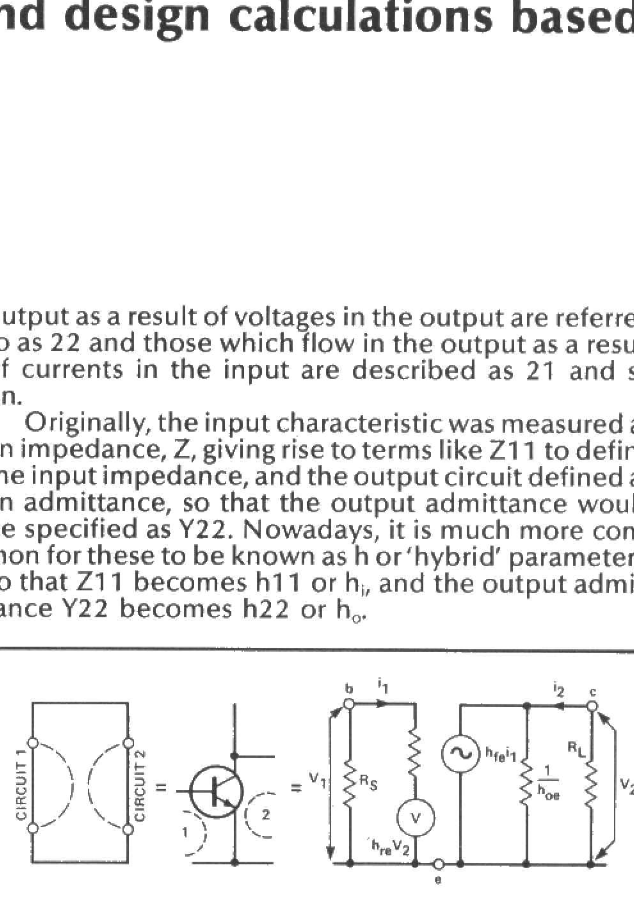


Fig. 1 A 'black box' representation of a junction transistor (left) and the equivalent circuit (right).

However, in addition to these we have the transfer characteristics, such as the forward current transfer ratio. This is written as hF if we are talking about DC values (usually referred to as static conditions) or hf if we are referring to dynamic (AC) characteristics. The reverse, or feedback parameter, h12, becomes h_r.

This is complicated a bit by the fact that all of these parameters are affected by the way in which the transistor is used. If it is used in the common emitter configuration with the signal applied to the base, the output taken from the collector, and the emitter tied to the 0V line, these various parameters become h_{FE} or h_{fe}, h_{oe}, h_{re} and so on. Similarly, if one ties the base to a common supply line potential, and applies the signal to the emitter, these parameters would be defined as h_{fb}, h_{ob}, and h_{rb}.

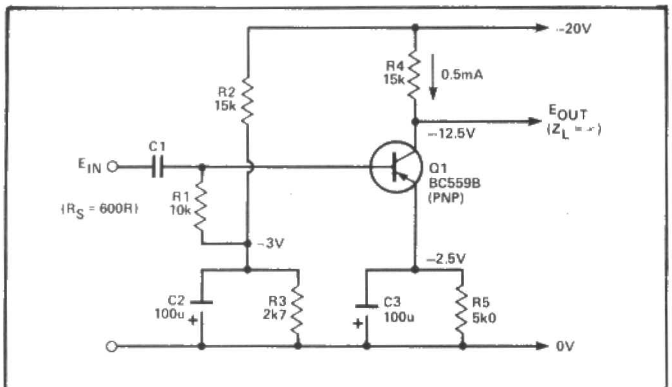


Fig. 2 A practical, common-emitter transistor gain stage which may be used for performance calculations.

Unlike valves and FETs, transistors have a DC conductive path between their three connections, so the output impedance is influenced by the input circuit impedance and vice-versa, and all of these including the current gain, are influenced by the operating current of the device.

A fairly full data sheet for a transistor should include graphs which show the way in which h_{FE} varies as a function of operating current. Ideally it shouldn't vary very much, and in the better modern types it doesn't. The graphs will also show the way in which the input impedance will vary with emitter current, but this will usually be quoted only for the common emitter configuration since this is the most widely used arrangement. If this isn't quoted, a fairly useful rule of thumb is that the input impedance (h_{ie}) is 25x the current gain for a 1mA emitter current, and increases, roughly in proportion, as the operating current is decreased. One should also find values for the output admittance, as μs or μA/V, and the reverse transfer ratio, hre.

The formula for calculating voltage gain, in the common emitter configuration shown in Fig. 2, is —

$$A_v = -\frac{h_{fe} \times R_L}{h_{ie} + R_S + \Delta_{he} \times R_L}$$

Δhe, the common emitter configuration correction factor ($h_{ie} \cdot h_{oe} - h_{fe} \cdot h_{re}$) is often small enough to be ignored, so the gain equation simplifies to —

$$A_v = -\frac{h_{fe} \times R_L}{h_{ie} + R_s}$$

Let's take a genuine example, such as the Mullard BC559, and go through these calculations for an operating current of 0.5mA. The gain of the circuit shown in Fig. 2, at a frequency in the AF range where the impedances of C1, C2 and C3 are small enough to be ignored, can be calculated using the published data:-

$h_{fe}=270$ $\qquad h_{ie}=10k$

$h_{oe}=25uA/V.$ $\qquad h_{re}=0.001.$

which gives a value of 0.52 for Δhe.

However, we have to take into consideration the source impedance (R_s), which in this case I have assumed to be a signal generator with a 600 ohm output. This must be added to h_{ie}.

$$A_v \quad \frac{270 \times R_l}{10k + 600 + 0.52 \times R_l}$$

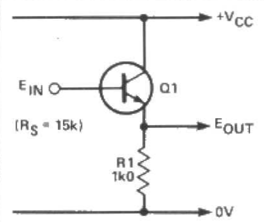
so the voltage gain becomes —

$$= -\frac{270 \times 15k}{10k6 + 0.52 \times 15k}$$

This is a very favourable condition, since I have also assumed an output impedance which is very high in relation to R4. If, however, the transistors were driven from a similar stage, where the output impedance is R4//Z_{oe} (40k//15k = 10k9), and it was loaded by the input impedance of a similar transistor, (Z_{ie} = 10k), the gain would come down to —

$$A_v = \frac{-270 \times 10k9//10k}{20k9 + 0.52 \times 5k2}$$
$$= 60$$

which is a much more typical figure.



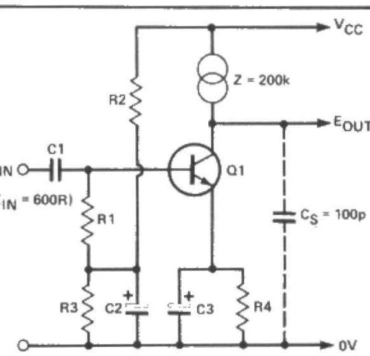


Fig. 3 A transistor arranged as an emitter follower.

Fig. 4 A high gain transistor stage.

Another useful calculation to be able to make is that to discover the input and output impedances of the impedance converting emitter follower circuit of Fig. 3. This is,

$$Z_{in} = (1+h_{fe}) \times R1,$$

and

$$Z_{out} = R_s/(1+h_{fe}) \text{ // } R1.$$

For a transistor such as the BC559, driven from a 15k source, the output impedance will be 52 ohms and the effective input impedance will be 271k.

The lesson which can be drawn from this is that, for high stage gains, low source impedances and high output impedances are imperative. However, there are snags. The first of these concerns the effect of output stray capacitance in parallel with the load.

Let us assume, in the case of the circuit shown in Fig. 4, that we we have contrived a constant current source as the collector load and this has an effective dynamic impedance of 200k at a collector current of 0.5mA. Using the circuit parameters of Fig. 2, this will give us a gain of 471 at lowish audio frequencies, and if we are driving an emitter follower or similar high impedance load we should not diminish this too much.

However, suppose we have a stray capacitance of 100pF in parallel with the output circuit. The output impedance will then decrease with frequency until, at about 7kHz, the stage gain will have fallen to half its low frequency value.

An aspect of this capacitance load effect which is familiar, and worrying, to audio amplifier designers is the combined effect of a constant current source load and stray capacitance when the amplifier is asked to

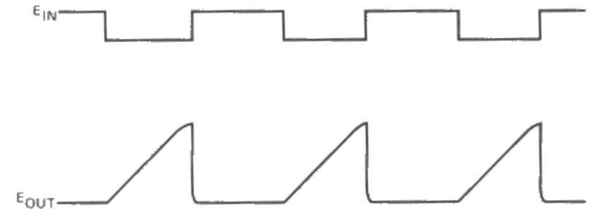


Fig. 5 Slew rate limiting caused by stray capacitance on a constant current source load.

handle a waveform having a rapidly rising voltage transient. I have shown this in Fig 5.

With the circuit shown, the amplifier stage may behave quite well on negative-going transients when the transistor, Q1, can pump current into the load, but on a positive-going waveform, the rate of charge of the capacitor is strictly limited by the constant-current source to 0.5mA, which gives a beautifully linear charging rate to the capacitance. This is lovely in the time base generator of an oscilloscope, but audibly very nasty in an audio amplifier. It gives rise to the defect known as 'slew rate limiting', which is one of the all-too-frequent causes of displeasure in less than high fidelity.

Another related problem inherent in the transistor is that of the Miller effect, due to the capacitance between the base and collector. Since the stage inverts the phase of the signal, at least on non-inductive loads, the side of the internal capacitor electrically connected to the output will rise in potential as the input side falls. If the gain of the stage is M, this has the effect of making the capacitor look like M+1 times its static value, as shown in Fig. 6.

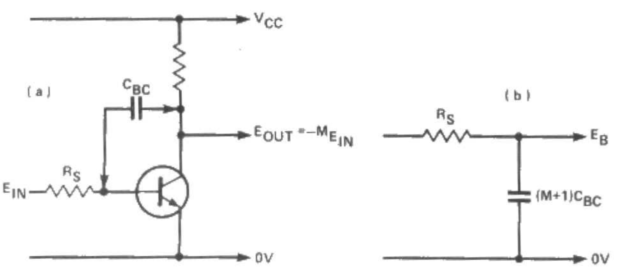


Fig. 6 Miller effect, whereby inherent capacitance between base and collector is magnified in value.

Supposing, therefore, that the stage gain is 150x, and the base-collector capacitance is 5pF, the actual capacitance seen at the transistor end of the source resistor is 5 x 150pF ≒ 750pF, which will have a considerable effect on the HF response of the circuit.

Other Parameters

Noise figure This is expressed in decibels, and is a measure of the extent to which the transistor input noise (output noise divided by stage gain) is worse than that which would have been due just to the input resistance on its own. All resistors generate noise, the higher the resistance value and the higher the temperature the worse this will be. The formula is —

$$V_n = \sqrt{4 \times K \times T \times \delta f \times R}$$

where K is Boltzmann's constant (1.38×10^{-23}), T is the absolute temperature (°K,) and δf is the bandwidth.

A typical graph showing the way the noise figure of a transistor varies with collector current and source resistance is shown in Fig. 7. Since the noise will increase at high input resistance values anyway, the best transistor to use if one wants the lowest noise is the one which will give a low noise figure at the lowest useable input resistance.

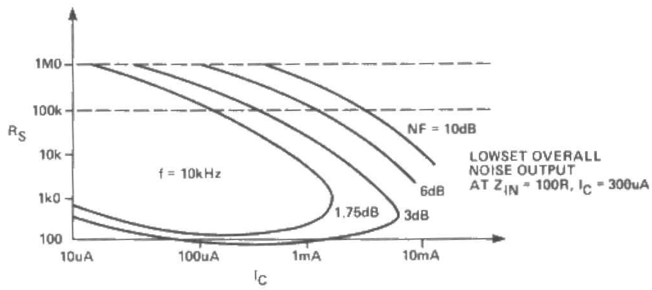


Fig. 7 The noise performance of a BC559 as a function of input resistance and collector current.

Happily, improvements in device manufacture have led to better characteristics, so, if you have a choice, use a device with a high 2N or BC number, rather than a low one. A BC549 is likely to be a better device, at the same cost, than a BC109, since these are both of the same type, only differing in date of design. Surprisingly, PNP small signal devices are better than NPN in this respect because the current flow in the base region — which is of N type — is due to electrons rather than holes.

Transition frequency As the operating frequency increases, so the current gain of a transistor will decrease. NPN devices are normally better than PNP ones in this respect, and since the problem is due to electron/hole mobility in the base and collector regions, devices with thin, highly doped base and collector layers, which will inevitably have a relatively low breakdown voltage, will be best in this application.

The parameter f_T can be thought of as the frequency at which the current gain will have fallen to unity.

Breakdown voltage This can be due to several mechanisms, and is usually destructive unless the current which can flow is limited by some external resistance to a value which does not cause the local thermal dissipation of the device to exceed a safe value.

One of the mechanisms is punch through, which occurs when the depletion layer in the base region resulting from the applied collector voltage extends, as V_c is increased, until it reaches the emitter region. When this happens, the base effectively loses its identity and there is no longer a PN junction to prevent current flow. If the collector region is heavily doped to allow high current flow, the number of minority carriers diffusing into the base will be greater and the depletion layer wider for any given applied voltage, leading to a lower punch through potential.

A second mechanism is the Zener effect. In a highly doped material, a reverse bias will cause the valence band (containing minority carriers) to overlap the conduction band in the semiconductor junction (containing majority carriers, ie, electrons) and current will flow. A small-signal transistor can be used as a cheap

	COMMON EMITTER	COMMON BASE	COMMON COLLECTOR
VOLTAGE GAIN	$\frac{-h_{fe} R_L}{h_{ie} + \Delta_{he} R_L}$	$\frac{(h_{fe} + \Delta_{he}) R_L}{h_{ie} + \Delta_{he} R_L}$	$\frac{(1 + h_{fe}) R_L}{h_{ie} + (1-h_{re} + h_{fe} + \Delta_{he}) R_L}$
CURRENT GAIN	$\frac{h_{fe}}{1 + h_{oe} R_L}$	$\frac{-(h_{fe} + \Delta_{he})}{1-h_{re} + h_{fe} + \Delta_{he} + h_{oe} R_L}$	$\frac{-(1 + h_{fe})}{1 + h_{oe} R_L}$
INPUT IMPEDANCE	$\frac{h_{ie} + \Delta_{he} R_L}{1 + h_{oe} R_L}$	$\frac{h_{ie} + \Delta_{he} R_L}{1-h_{re} + h_{fe} + \Delta_{he} + h_{oe} R_L}$	$\frac{h_{ie} + (1-h_{re} + h_{fe} + \Delta_{he}) R_L}{1 + h_{oe} R_L}$
OUTPUT IMPEDANCE	$\frac{h_{ie} + R_S}{\Delta_{he} + h_{oe} R_S}$	$\frac{h_{ie} + R_S(1-h_{re} + h_{fe} + \Delta_{he})}{\Delta_{he} + h_{oe} R_S}$	$\frac{h_{ie} + R_S}{1-h_{re} + h_{fe} + \Delta_{he} + h_{oe} R_S}$

NOTE: $\Delta_{he} = h_{ie} \cdot h_{oe} - h_{re} \cdot h_{fe}$

CIRCUIT LAYOUT

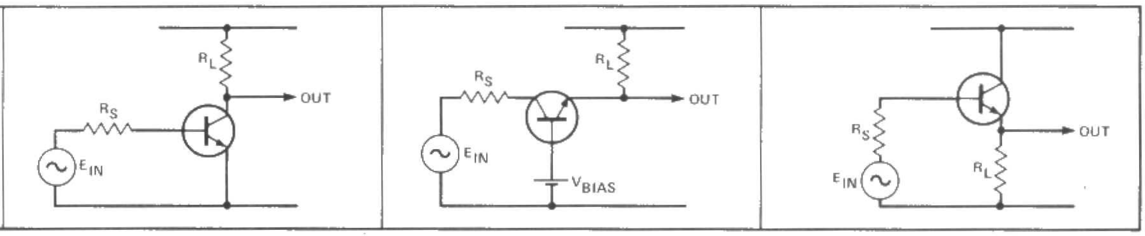


Table 1 Junction transistor performance calculations using h parameters.

zener diode of about 5-6V if it is connected with its emitter reverse biased in relation to its base. This is because the emitter is usually a very heavily doped region. Normally, if the current is held to a sensible level, no damage will occur. The collector should be connected to the base in this application, to keep it from joining in as shown in Fig. 8.

A third mechanism, avalanche breakdown, occurs in lightly doped high voltage transistors if too high a voltage is applied. In this, carriers entering the depletion region are accelerated by the applied potential and, if their velocity is high enough, collisions within the material will generate ion-pairs and further carriers. The result is much like an avalanche, and usually just about as welcome. An exception to this is in avalanche diodes where this mechanism is used to beneficial effect.

In transistors, avalanche effects are greatly influenced by the external base-emitter circuit resistance, and this is the reason why, in general, high voltage and power transistors require conditions of use in which the base circuit resistance is low.

Power Transistors

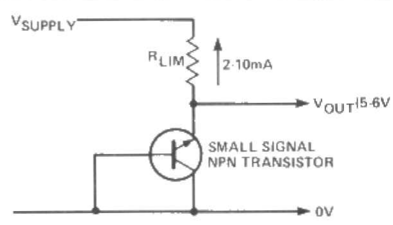
In principle, one can do all the calculations for power transistors that one can for small signal ones, except that the manufacturers are a lot less forthcoming about the input and output h values. This is because power devices are mainly only used in applications where, as emitter followers or drivers of low impedance loads, the stage gain is a lot less important than the ability of the device to feed current into the load or withstand the voltage swings involved without breakdown.

The parameters one is likely to find published in respect of power transistors, in addition to the ones which are obvious like total power dissipation and safe operating area (which we looked at previously), are those which relate to its operational voltages and switching times.

Of these, the ones which are likely to be of interest, say, to an audio amplifier designer, are the collector and base saturation voltages. These will be specified at certain base and collector voltages, and relate to the sort of voltage drop which is going to occur across the device when large quantities of current are delivered by it.

A further quality which would be of interest is the variation of current gain with collector current. Ideally, for lower distortion, this curve should be as flat as possible. Also, if one is seeking a high power output, the 'thermal resistance' of the transistor is important. This is usually specified in °C/watt, and infers a perfect stone-cold heat sink, so in practice, the thermal resistance of the heat sink will have to be added to this to

Fig. 8 A small signal transistor connected as a zener diode.



arrive, perhaps, at a figure like 2.5°C/watt. The maximum junction temperature which is tolerable will depend on how long you intend the device to last. If you are worried about this, aim to keep your junction temperatures below 150°C, under the worst likely conditions. If one had a total heat-sink + transistor thermal resistance of 2.5°C/W, and the ambient temperature was 30°C, this would mean a maximum dissipation of (150-30)/2.5W, or 48 watts.

V_{ceo} sus., is the collector voltage at which the transistor will pass a continuous collector current, even when there is no base drive current at all. The manufacturers quote minimum values for this. In practice it means 'keep well below this voltage — unless you are only operating under pulsed voltage conditions'.

The normal maximum operating voltages (usually under relatively low current conditions) are defined as

V_{cbo}, which is the maximum voltage permitted between collector and base with the emitter open circuited; V_{ceo}, which is the collector/emitter maximum voltage with the base open circuit, and V_{cer}, which is the permitted maximum collector voltage with some specified value of resistance between emitter and base (see avalanche breakdown above).

V_{ebo} is the reverse biased emitter/base zener voltage, and is usually about 5V for power devices.

Where the power transistor is being used for fast switching applications, the various switching times become important. These are the delay time (td), which is the time which elapses after the application of a voltage to the base before any collector current begins to flow; the rise time; the fall time; and the storage times associated with the rise and fall of collector current, and which relate to the length of time it takes for the relatively slow moving holes in the base region to be eliminated.

This is particularly important when the current through the transistor is being turned off. It will not reach a zero value until the stored charge is dissipated, and this is dependent both on the external base-emitter circuit resistance and upon the emitter voltage. If the emitter is reverse biased to some value lower than the zener breakdown level, the stored charge will be removed more rapidly and this may be a critical factor in switching inductive loads.

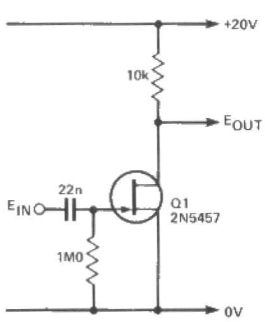


Fig. 9 A practical small signal amplifier stage using a FET.

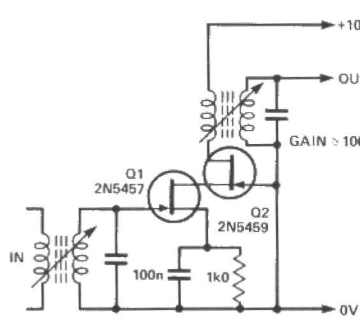


Fig. 10 A stable RF amplifier stage using cascode connected FETs.

Because of the larger junction areas all of the capacitance values for power transistors are much larger than for small signal devices, with values in the range 100-1000pF being common.

Junction Field Effect Transistors

Because these are voltage operated devices with a virtually infinite impedance gate electrode, gain calculations are much simpler, at least at low frequencies. As with junction transistors, HF calculations, usually with deliberate or unintentional inductance in the input and output circuits, are a highly complex business, best left to the specialists in this field.

The parameters which are likely to be specified are Y_{fs}, the forward transfer conductance, or forward trans-admittance, which is similar to the G_m, or mutual conductance, figure for a thermionic valve, and is usually expressed in mA/V; and the Y_{os}, or output admittance, of which the reciprocal is similar to the anode resistance of a valve.

Typical values of these parameters, for a 2N5457 FET, are 4-7mA/V at 0V negative gate bias, and 2μS, or 500k. A 2N5459, which has a gate cut-off voltage of about -5V instead of 1.5-2V for the 2N5457 and a zero gate-bias drain current of 10-15mA instead of 2-5mA, will have a higher zero gate bias Y_{fs}, probably in the range 6-10mA/V. The output impedance is, however, very similar. Junction FETs do have very high drain resistance values, which is why they make such good constant-current sources.

The formula for calculating voltage gain is a simple one:-

$$A_v = -\frac{Y_{fs} \times R_L}{1 + Y_{os} \times R_L}$$

For the common source configuration shown in Fig. 9, and with the component values shown, this becomes:-

$$A_v = -\frac{5 \times 10^{-3} \times 10k}{1 + \frac{10k}{500k}}$$

giving a value for stage gain of 49 at zero gate bias. However, as the negative gate bias is increased the mutual conductance falls, giving proportionately lower stage gains. Once again, I have assumed an infinite impedance load. A load of 10k would halve these stage gain values.

The input capacitance, C_{iss}, is typically 3-6pF, decreasing as the gate becomes more negative. The reverse transfer capacitance (or, more familiarly, the drain-gate capacitance) is typically 1-3pF, becoming less as the drain voltage is increased, and as the gate is made more negative. This is a bit high for stable working as an RF amplifier, but two similar FETs can be connected in cascode as shown in Fig. 10, to make a very stable RF amplifier.

The input noise figure for FETs will be expressed as nV per $\sqrt{Hz}$, and since this is independent of the source resistance value, the FET will have the least effect in worsening the input noise when the input circuit resistance is very high.

For example, the published figure for a 2N5457 at 25°C is 10nV/$\sqrt{Hz}$, which for a 20kHz bandwidth is 1.4μV. However, for the same bandwidth, the noise developed across a 1M resistor is 18μV, giving an effective FET noise figure of 0.6dB when used in this circuit. The break-even 6dB noise figure occurs for an input resistance of about 7k.

One of the areas in which junction FETs (and MOSFETs) score heavily in comparison with bipolar transistors is in terms of linearity, with a typical FET amplifier stage offering THD (Total Harmonic Distortion) figures in the absence of negative feedback some 10x lower than for a similar bipolar gain stage. Say, 0.5% THD instead of 5% THD for 5V RMS output. This arises because the FET has a very linear input voltage/output current relationship, especially at near zero gate bias voltages. This compares with bipolar devices which are only linear at very small input signal levels.

Small Signal MOSFETs

The characteristics of these are very similar so far as gain calculations are concerned to those of junction FETs, and the same formulae apply. However, the typical values of drain resistance are more similar to those of a junction transistor than to the junction FET.

Next month I propose to take a look at diodes, in all their various forms.

ETI

ELECTRON SECOND PROCESSOR

Speed-up your Electrons and watch your memory expand with a 6502 second processor, designed by John Wike with Electron owners in mind.

This article describes the addition of a second processor board to an Acorn electron, making 30K bytes of RAM available to BASIC (60k to machine code), and giving an increase in processing speed of up to three times.

The hardware will be described this month and the software next month, together with a complete assembly listing.

What about the others?

Although the term 'second processor' is usually associated with Acorn and their 'Tube' system, multiprocessor designs are found in several microcomputers in the business and scientific markets. Even the Sinclair QL contains two microprocessors, one to handle input/output and the other to do all the computing. So, although the circuit shown here is designed specifically for the Acorn machines, the concept is generally applicable.

It is relatively straightforward to design a circuit board with a processor and some RAM on it, and to interface it with an existing computer system. The real problem is the software, machine code of course, to handle the new hardware.

As the host machine probably has the screen RAM within its memory map, it must be assumed that it will retain the input/output handling functions. This means that the language (usually BASIC) will operate in the second processor.

It is necessary to know how to intercept the input/output routines (PRINT, INPUT, SAVE, LOAD, etc.) so that the data will be transferred to or from the second processor's memory instead of the host's. Routines can then be written to reside in each processor's memory and allow them to communicate with each other transparently, so that the user will not be aware of any difference in operation from the basic machine.

All this sounds involved, but given a machine that is well supported by reference material and ROM listings, or your own skill at disassembly, it is by no means impossible. So if you are interested have a go!

2P or not 2P?

The owner of an Acorn machine does not need to worry about the foregoing because this article will cover all the ground. He or she will however have to decide whether it is worthwhile adding a second processor to the system. There are several advantages to balance against the effort involved:

Speed

The benchmark system has gained widespread acceptance as a qualitative assessment of the processing speed of a computer. For a full discussion of benchmarks the reader is referred to the February 1985 edition of Computing Today. Each test consists of 1000 iterations of specific instructions, the times for which are given in Table 1. Also included for interest are the timings for the BBC computer, taken from the Computing Today article. In Mode 6 the unexpanded Eelectron is approximately 50% slower than the BBC, and in Mode 0 it is 250% slower! With the E2P board fitted it is approximately the same as the BBC in all modes.

Memory

The display memory in the Electron can consume between 8K of RAM in Mode 6 and 20K of RAM in Modes 0, 1 and 2. Add to this the 3.5K used as operating system workspace, up to 1.5K for user-defined characters and an extra 3.75K if the Plus 3 disc drive is fitted, and out of a total of 32K there might only be 3.25K available for programs. The E2P board contains 64K RAM, 30K of which can be used from BASIC whatever the configuration. Machine code programs can use a massive 60K.

Processor

The first requirement of the design was that the hardware and software should react with the Electron operating system in the same way as the official 'Tube'.

Benchmark	Mode 6	Mode 0	E2P	(BBC)
1	0.93	2.11	0.68	0.8
2	4.01	9.35	2.99	3.1
3	11.54	26.97	8.43	8.3
4	12.27	28.86	8.95	8.7
5	12.85	30.15	9.37	9.1
6	19.51	45.72	14.35	13.7
7	30.09	69.88	22.24	21.3

Table 1 Benchmark timings for the Electron with and without E2P.

This is a ULA with eight bi-directional registers, addressed at FCE0 h to FCE7 h, of which seven are used by the support software and only one, at FCE5 h, is accessed directly by the operating system for data transfer during, for example, LOAD and SAVE. So the circuit must detect accesses at FCE5 h and interrupt the second processor to allow it to pass the required data. The other registers can be at any convenient address, since they have their own support software.

The only storage device on the board is the RAM. The top 256 bytes of that are accessible to the Electron, so that several locations can be used as the bi-directional registers. Also, as this is the area where the 6502 goes at Reset, the Electron can control its reset and transfer sufficient code there beforehand to allow it to "boot up'. After that the rest of its operating system can be sent via the data byte at FCE5 h.

When deciding where in the Electron memory map to locate this 256 byte block, it was remembered that sideways ROMs are given the opportunity to initialise themselves at BREAK and to declare themselves during the *HELP command. The block is therefore addressed as a sideways ROM and the first eleven or so bytes are taken up with the necessary data for it to be recognised by the operating system. They also contain a jump instruction so that the 'ROM' software can be in the main program in the Electron RAM.

In order to refresh the dynamic RAM the processor is interrupted every 1ms and a specific routine scans 128 bytes in 64 μs. On alternate interrupts it scans another 128 bytes to include all the rows in the RAM. This results in a time overhead of 6% which is considered acceptable by the author. Because the refresh is software controlled there is no facility for a hard reset of the processor. Instead, the 'sideways ROM' routine issues an initialisation request on BREAK.

Interfacing

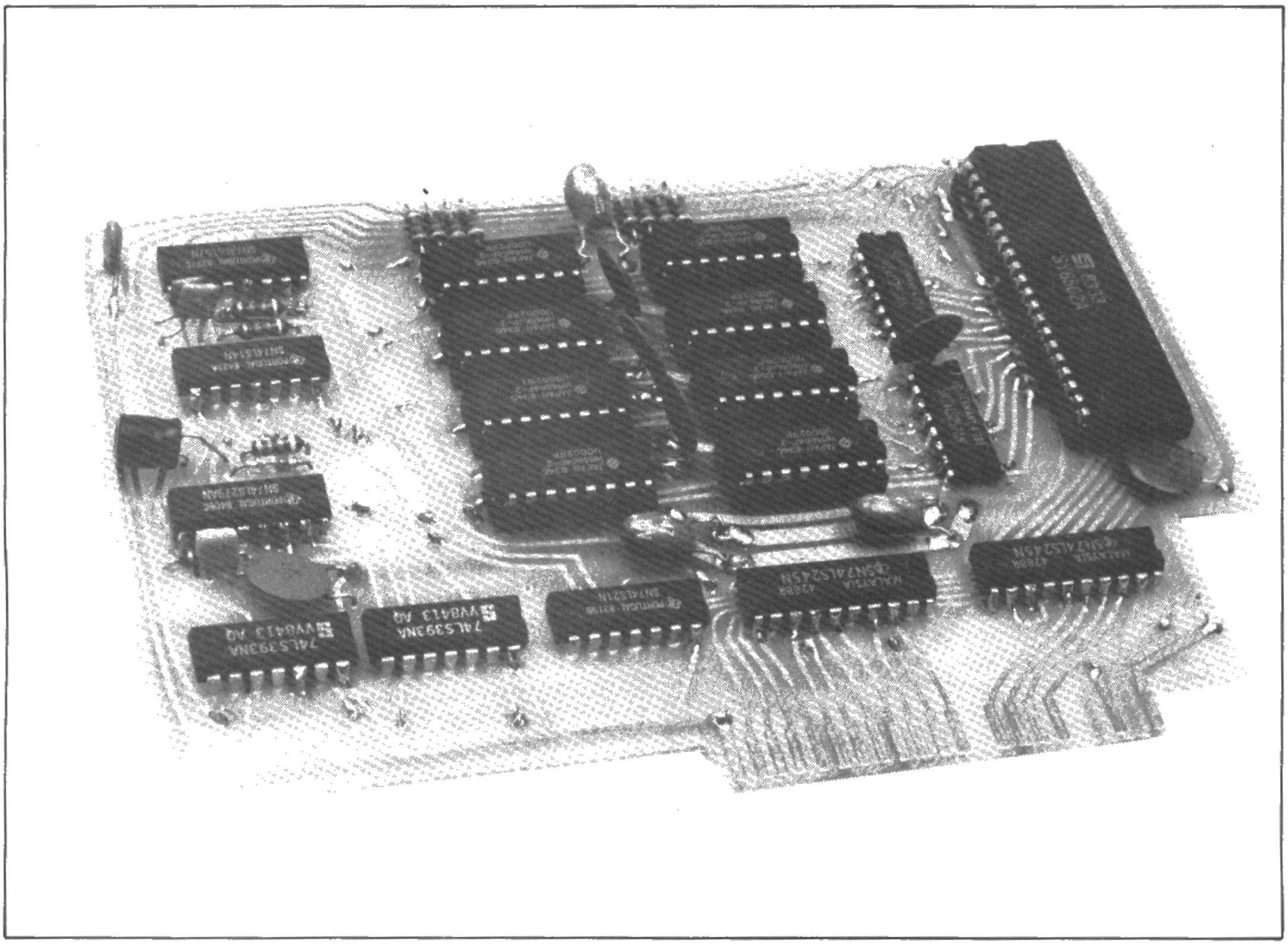
The board is designed to slot into one of the cartridge sockets on the Plus One interface unit, which provides some of the address decoding. For those people without a Plus One, a circuit is shown allowing connection to the basic Electron.

Current consumption of the board is about half an amp, which the author's machine was able to cope with. If a lot of other devices are drawing power, it may overload the supply. A link (LKI) is provided to disconnect the 5 volt line from the edge connector and an alternative supply can then be connected to the board.

Construction

Construction of this project is straightforward but you are recommended to use a fine tipped soldering iron, and to check the board closely to see that no stray bits of swarf or solder are shorting tracks.

As this is a double sided PCB and is not plated through, the first



The author's prototype second processor board (some changes have been made in the final version).

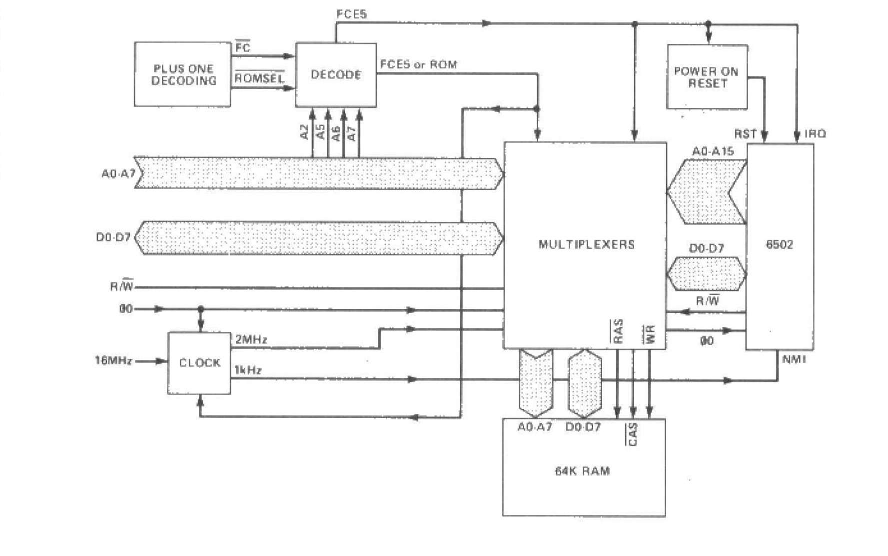


Fig. 1 Block diagram of the second processor board.

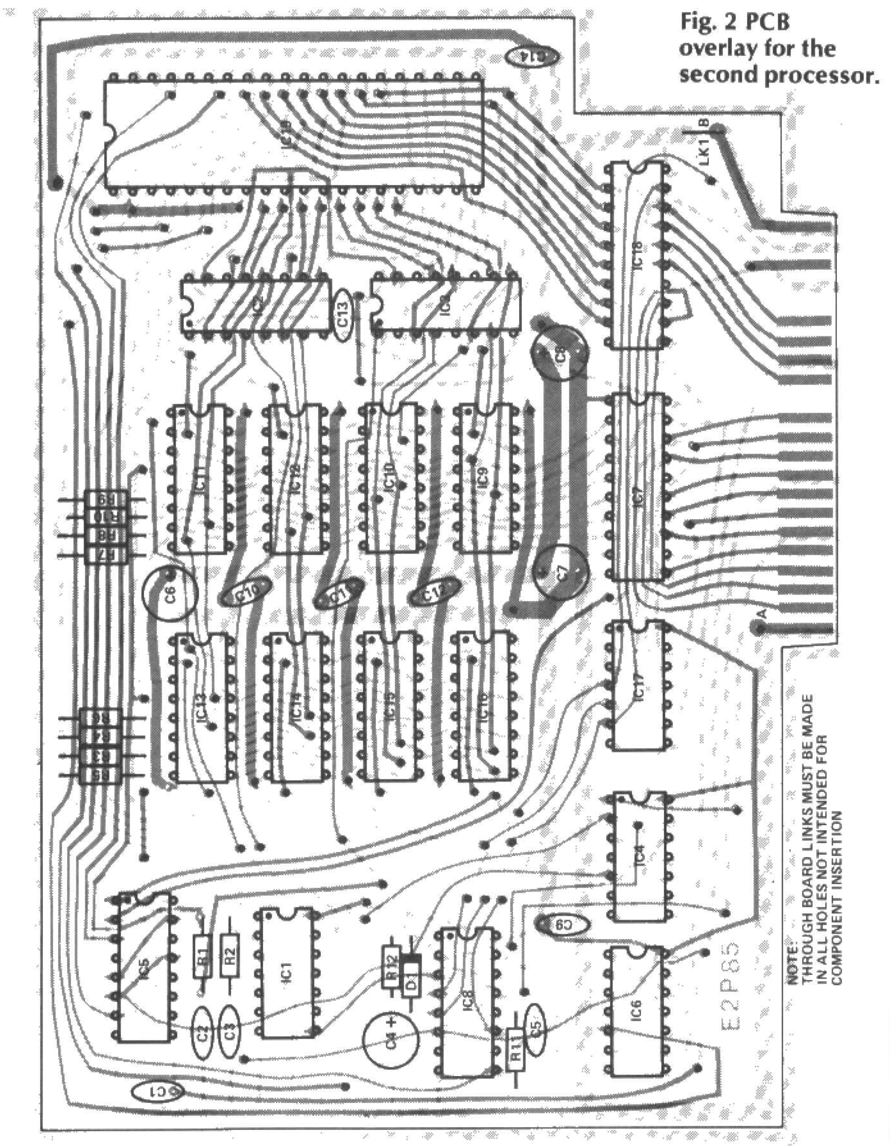


Fig. 2 PCB overlay for the second processor.

thing is to insert all the links and solder them on both sides of the board. Take special care not to miss the ones underneath ICs as these will be impossible to fit afterwards.

Next fit all the ICs except the RAMs and the processor, soldering

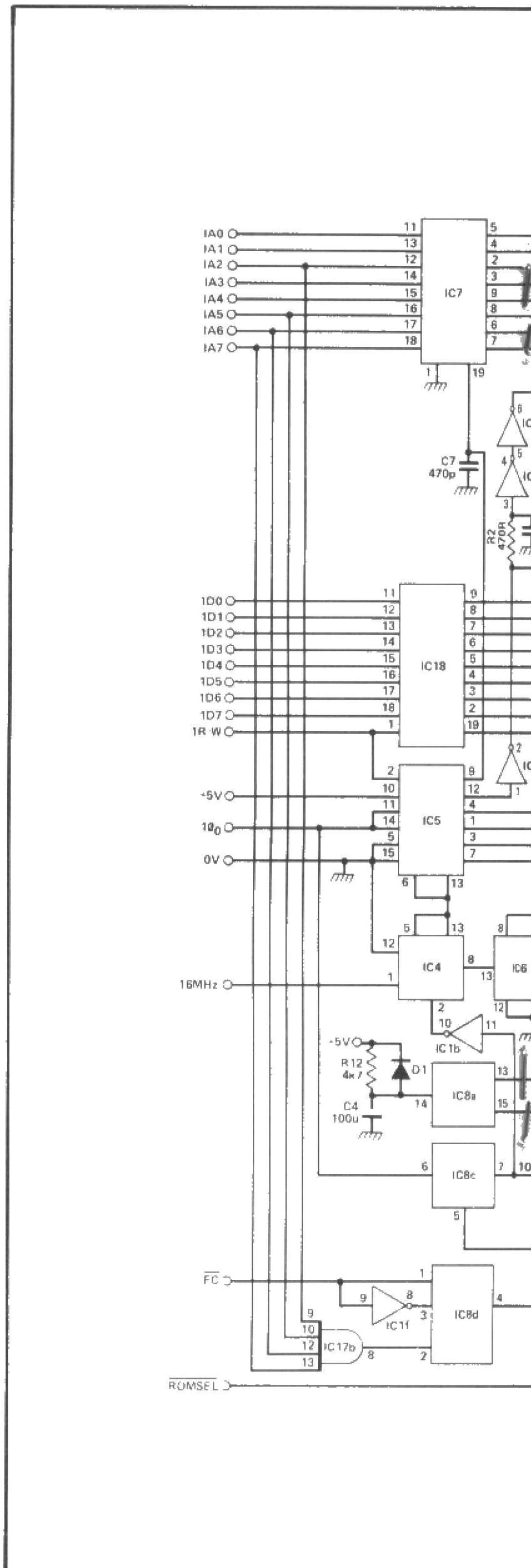


Fig. 3 Circuit diagram of the second processor b

their leads on the bottom, top or both, as necessary.

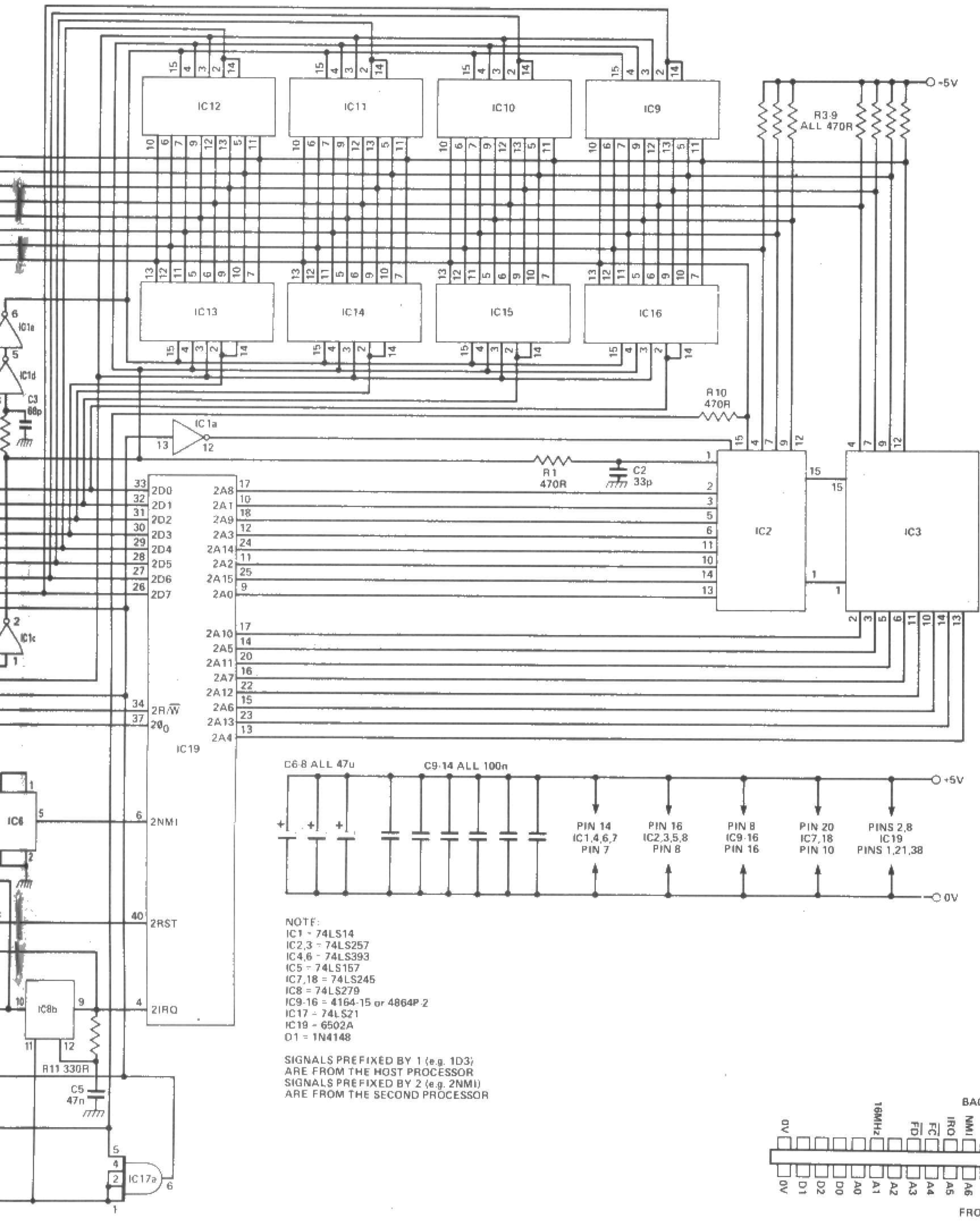
Next fit the resistors, capacitors and diode. Some of these components need to be soldered on both sides of the board.

Now fit the sockets for the RAMs and processor. Use insulating tape to protect the through-board links before inserting the sockets.

If you intend to power the board from the Electron's 5 volt line fit the link LK1. Otherwise, connect the external supply wires to points A (0 volt) and B (5 volts).

Finally, insert the RAMs and processor into their sockets.

If you do not have the Plus One unit you will now have to construct the interface circuit. This could be done on Veroboard and then connected, along with the second processor board, to the



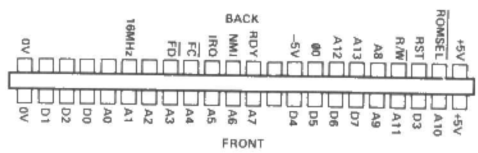


Fig. 4 Plus One cartridge socket edge connector.

r board.

HOW IT WORKS

The second processor is reset at switch on by latch IC8a with C4 and R12. Diode D1 ensures that C4 will be discharged quickly at switch off.

IC8 is a quad S-R latch with Set overriding Reset. Sections c and d are used to provide extra AND functions.

Decoding of the host processor address bus is performed by IC17, IC8d and ICIf. When either the sideways ROM or FCE5 h are accessed, the output of IC17a will go low. This signal enables the data bus buffer, IC18. It also disables the second processor address multiplexers IC2 and IC3, after being inverted by IC1a, and it operates the control line multiplexer IC5. IC5 determines which processor's R/W̄ and clock signals will be applied to the RAM — when Pin 1, select, is low the second processor clock and R/W̄ times are effectively disabled.

The second processor 2MHz clock is generated by IC4 dividing down the master 16MHz oscillator. Further division takes place in IC4 and IC6 to give the 1ms NMI singal. Note that as the processor only responds to negative edges there is no need to provide short pulses.

The output of IC17a is combined with the host processor clock in IC8c, which triggers the 15μs IRQ monostable IC8b. The monostable is inhibited during ROM selection by the input at pin 11 so that it will only operate during an access at FCE5h. The monostable output is also fed to IC8a to clear the second processor reset.

The output of IC8c goes via IClb to set the second processor clock in phase with the host's during host access. Because the clocks are in phase, the control multiplexer IC5 can be guaranteed to switch when they are both low.

Tri-state buffer IC7 with resistors R3-R10 performs the address multiplexing function for host processor addresses. It is enabled during the first part of a host access to give the row addresses for the RAM's. then it is disabled and the resistors provide the column addresses. If it is a ROM address, IC8d output will be high and page FF h will be accessed. For address FCE5 h, IC8d will be low and page FE h will be accessed.

The RAS signal to the RAMs is provided by IClc and the CAS signal by ICld and ICle from the delay circuit R2-C3.

PARTS LIST

INTERFACE

RESISTOR	
R13	470R
CAPACITOR	
C15	220p
SEMICONDUCTORS	
IC20	74LS30
IC21	74LS27
IC22	74LS20
IC23	74LS139
IC24	74LS74

MISCELLANEOUS

Veroboard, 22-way double sided socket to fit E2P edge connector, 25-way double sided socket to fit Electron edge connector.

Electron with a short length of ribbon cable and a 25 pin double-sided edge connector.

Setting up

Before switching on, check the board very carefully for shorted tracks and the orientation of ICs, diodes and electrolytic and tantalum capacitors. To ensure that the Electron will will not be damaged check every contact on the edge connector with a meter for shorts to either the 0 volt or 5 volt supply lines.

Connect the board and switch on. You should get the start-up screen as usual. If not, then switch off and check again for shorts.

If you can get hold of a double-beam oscilloscope, connect a probe to pin 9 of IC8 and enter and run the following program:

10 A%=?&FCE5:GOTO10

You should see on the 'scope a negative going pulse 15 ms wide. If it is a different width adjust the values of R11 and/or C5 to get it as close as possible.

Now conect one input of the scope to ICI pin 1 and the other input to ICI pin 6. The negative going edge of the signal on pin 6 should occur between 120 and 150 ns after the positive going edge at pin 1. Adjust R2 and/or C3 as necesary.

Before trying the system in earnest you will have to switch off then on again in order to hard reset the second processor.

The necessary software will be included in next month's article, but in the meantime a copy of the assembly code is available on tape from the author. Alternatively, if you send a Plus Three disc it can be stored on that together with the machine code as a !BOOT file so that pressing shift-break will automatically boot in the second processor. See Buylines for details.

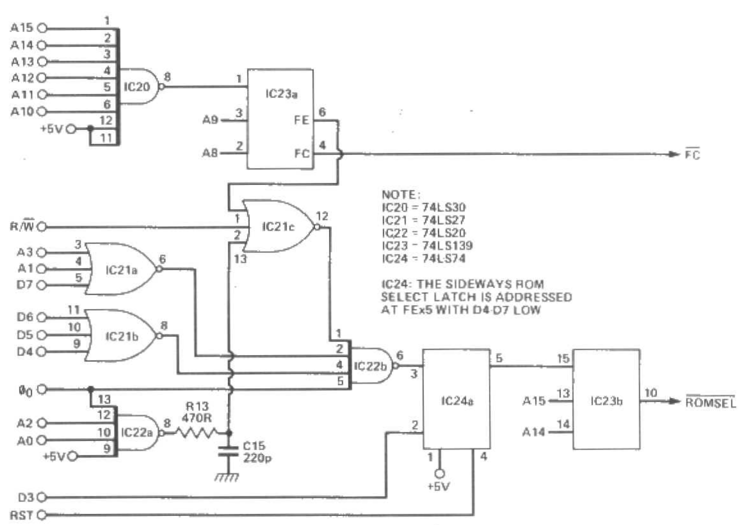


Fig. 4 Suggested interface circuit to link basic Electron and the second processor.

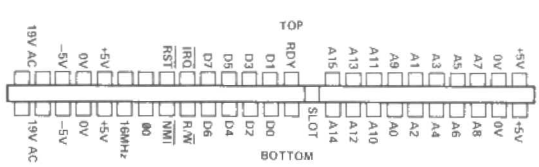


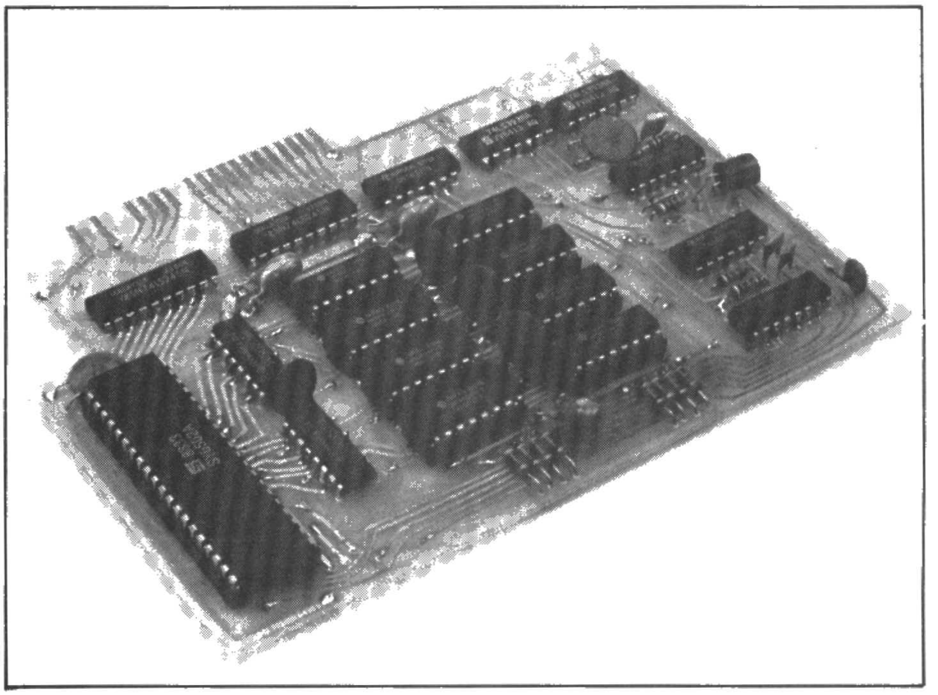
Fig. 5 Electron edge connector

PARTS LIST

MAIN BOARD

RESISTORS (all 1/4 watt)	
R1,2,3,4,5,6,7,8,9,10	470R
R11	390R
R12	4k7
CAPACITORS (all ceramics unless stated)	
C1	470p
C2	33p
C4	100μ electrolytic
C5	47n
C6, 7, 8	47μ 10V tantalum
C9,10,11,12,13,14	100n
SEMICONDUCTORS	
IC1	74LS14
IC2,3	74LS257
IC4,6	74LS393
IC5	74LS157
IC7,18	74LS245
IC8	74LS279
IC9,10,11,12,13 14,15,16	4164-15/4864P-2
IC17	74LS21
IC19	6502A (2Mhz)
D1	1N4148

MISCELLANEOUS
40 pin DIL socket, 8x16 pin DIL sockets, wire for links.



BUYLINES

All the components are available readily from advertisers in ETI. The PCB and software are available from the author, John wike, at 9, Lon-y-Garwa, Caerphilly, Mid-Glamorgan. The price of the PCB is £12, software on tape is £3.50, and on your disc £2.00, inclusive of postage. if you send a disc please state whether you wish to have the !BOOT file put on it.

ETI

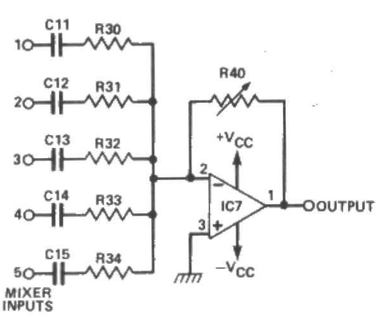
LOW COST AUDIO MIXER

This modular mixer from John Linsley Hood is not super-fi, but it is cheap, portable and so versatile you can use any source, except the kitchen sink.

The instrument described here was designed and built for the use of the local 'Talking Newspaper for the Blind', and the circuitry shown was specifically tailored for their needs — which were, basically, for a control console containing the necessary electronics, and fader pots, so that the operator could mix in various voices with programme material from other sources — disc, radio or tape — to produce a final stereo tape cassette. This would then be duplicated for distribution to subscribers.

The general layout is versatile enough for the actual inputs to be modified for other types of input. I will show some of the other input circuits which may be slotted in, in place of, or in addition to, the existing layouts.

One general requirement for all such mixer consoles is the provision of a reasonably quality stereo headphone monitor facility, allowing the control engineer to hear just what he or she is putting on to the tape. The unit has been designed to be operable from a battery DC supply. It could be used as a fully portable 'studio' in conjunction with a suitable battery operated cassette recorder.



NOTE: FOR COMPONENT VALUES REFER TO MAIN CIRUIT DIAGRAM.

Fig. 1 The central circuit of a virtual earth mixer.

No VU metering system has been provided since it is assumed that the recorder used will have this facility.

Basic Layout

The circuitry is organised around the virtual earth mixer layout shown in Fig. 1, which can be hooked up easily around an IC op amp and allows as many inputs as one wishes to be combined together into a common signal (although only five are shown in the diagrams).

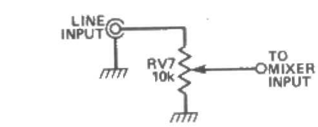
This is a very powerful technique for mixing inputs, and has the great benefit that there is no leakage back from one input into another, since the inverting input of ICI in this layout really does look like an earth point to the incoming signals. This also implies that the input impedance of the circuit is determined by the values chosen for each input resistor, R30, R31 . . . .

The overall gain of the stage is determined, for any one input channel, by the ratio of R40:Rin (Rin being the input resistor). If R40 is variable (as shown in Fig. 1 but *not* in the main circuit diagram), the gain of all the input channels may be reduced or increased simultaneously.

The various inputs to this mixer stage are obtained from input stages of the types described below.

Line Input Stage

In the simplest case, where a signal is obtained from a radio or tape recorder having a line output socket — which will give 300-700mV output at a lowish impedance — all that is required is a simple slider pot connected as shown in Fig. 2. On the other hand, if it is known that the unit may be used with signal sources



NOTE: FOR COMPONENT VALUES REFER TO MAIN CIRCUIT DIAGRAM

Fig. 2 A mono line input arrangement.

having outputs conforming to the DIN standard — in which the output is arranged to provide 1mV for each 1K of load impedancy — the alternative arrangement of Fig. 3 can be used.

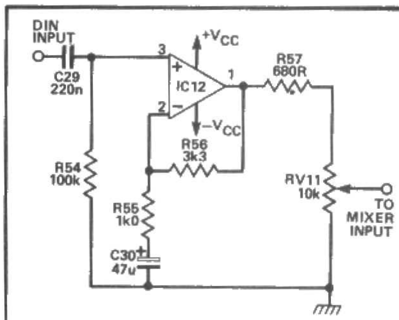


Fig. 3 DIN input stage.

This is quite a versatile system, and can be used with any input source where a flat frequency response is all that is needed, and where the input signal level will not exceed more than about 0.5V RMS.

Microphone Input Stage

This uses an identical circuit layout to that of Fig. 3, but with the values of R55 and R56 changed to R11 and R16 in Fig. 4 to give a higher gain, since the expected output signal level from the mic may be only 2-3mV. The input impedance is also made switchable between 100K and 4K7 (R1 and SW1 in Fig. 4) to suit either crystal or dynamic (moving coil)

microphones. Electret mics with a built-in FET buffer output could be used equally well with either.

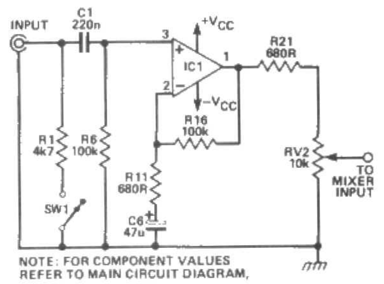


Fig. 4 Mic input stage

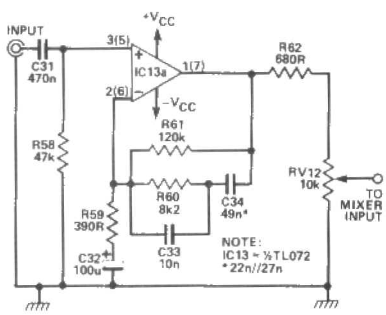


Fig. 5 Optional RIAA input stage.

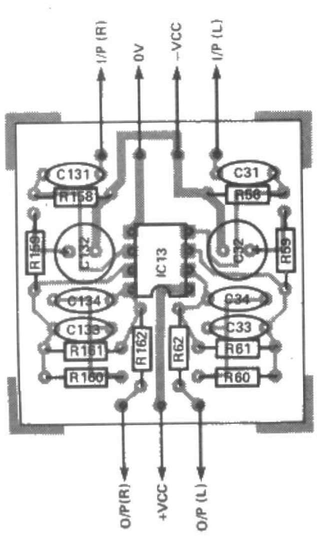


Fig. 6 PCB overlay for RIAA stage.

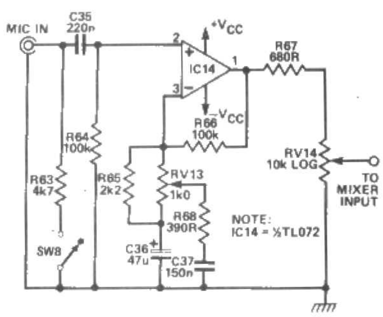


Fig. 7 Optional treble-lift mic input.

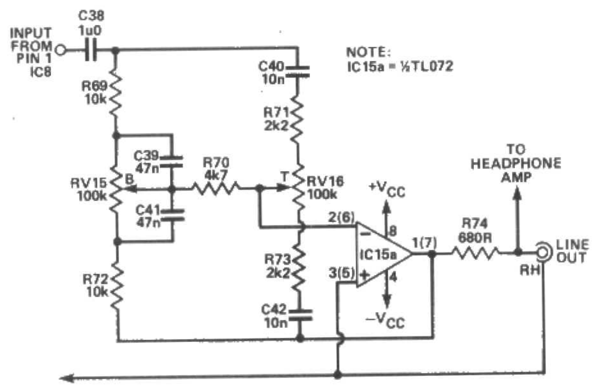


Fig. 8 Optional bass and treble lift-cut tone control stage.

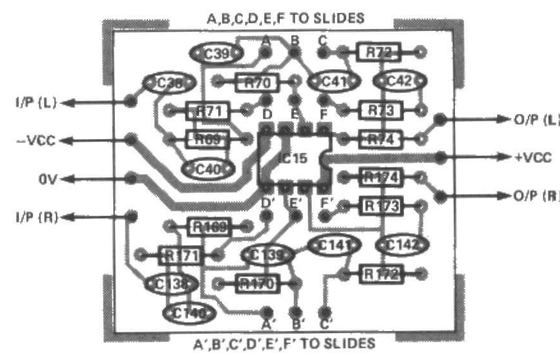
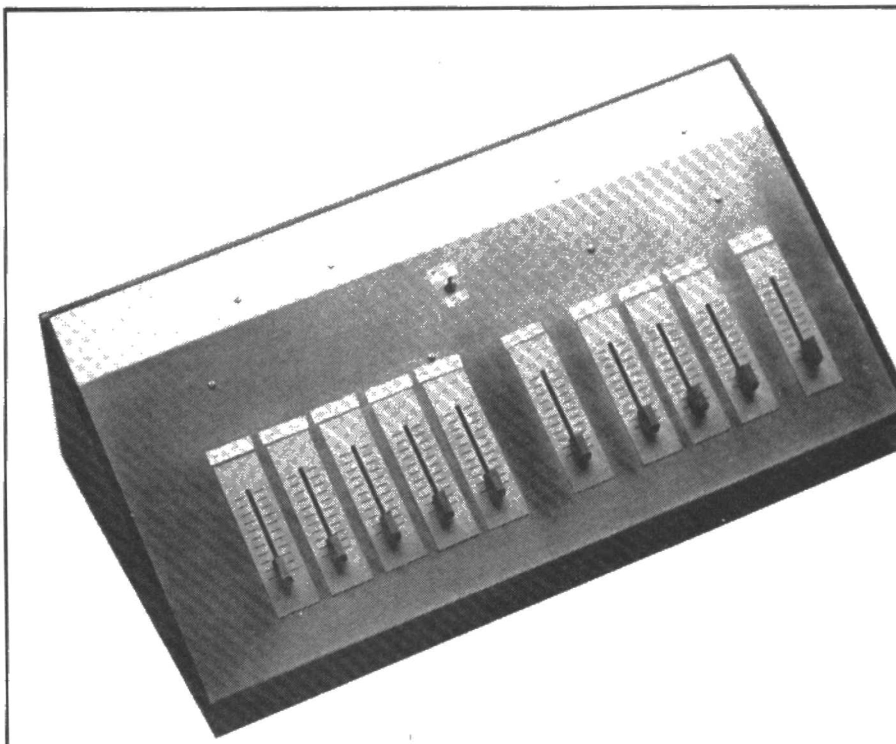


Fig. 9 PCB overlay for optional tone control stage (stereo).



Completed prototype mixer

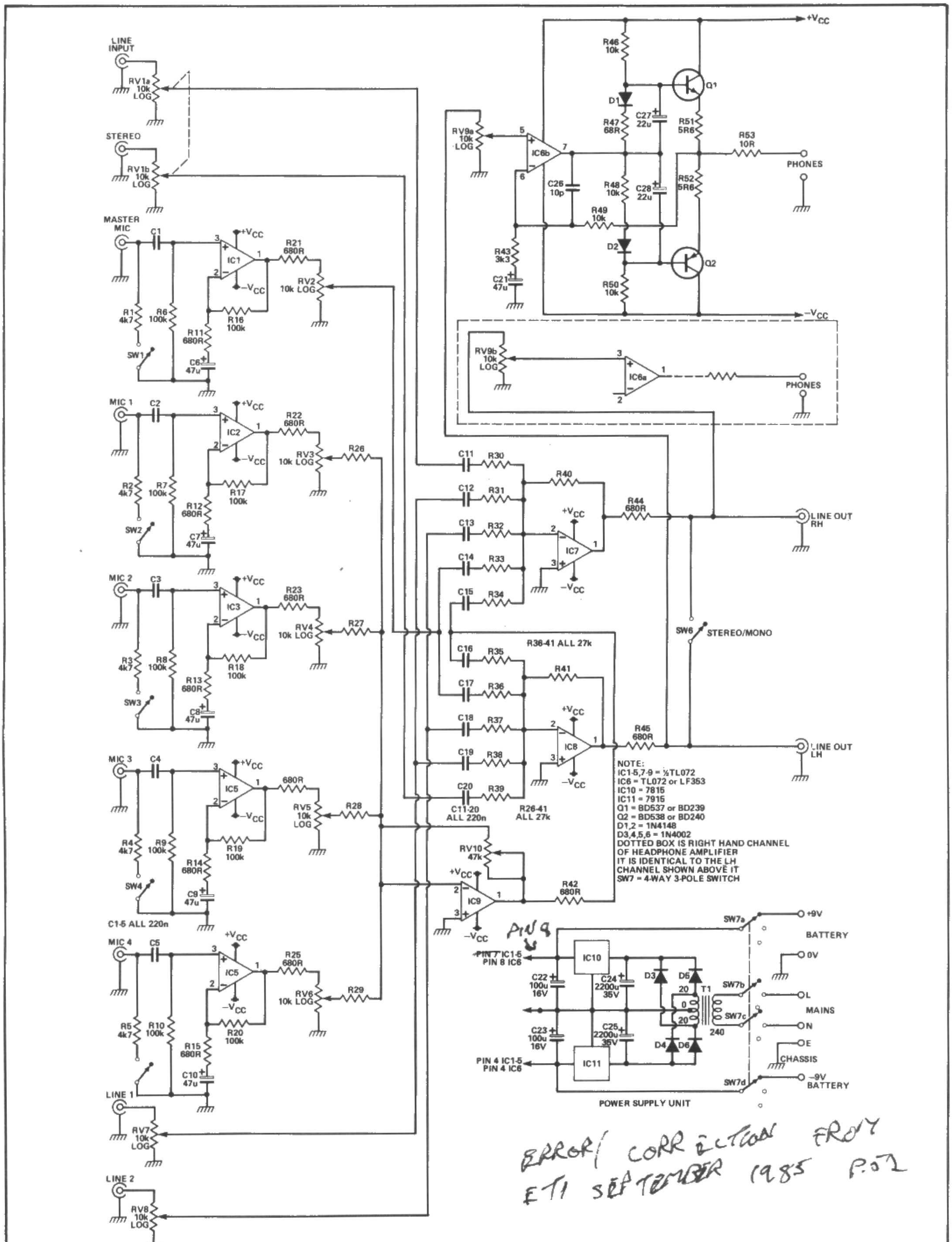


Fig. 10 Circuit diagram of the complete prototype mixer and Fig. 11 (opposite) overlays for the mixer and PSU boards.

Gramophone PU Inputs

This facility was not required for the actual unit which was built, but there is no difficulty in modifying the op amp input stage to provide the required gain and frequency response characteristics. The circuit for this is shown in Fig. 5. Since I am not aiming at the 'ultimate-fi' in this unit, I feel that a conventional series feedback layout, as used in 99.9% of domestic hi-fi amplifiers, will be quite adequate.

The op amp output resistors in the DIN, mic and RIAA stages (R57, R21 and R62, respectively), are included to prevent changes in the loading of the op amp, due to the setting of the output gain controls, which would alter the frequency response characteristically of the gain stage.

Headphone Output Stage

This is fairly conventional, and again uses an op amp as the gain block, to which some muscle power is added by the transistors Q1 and Q2. These are biased into class A by the diode/resistor network R46-R50, D1 and D2. A small capacitor, C26, is connected across the op amp to ensure HF stability. Several pairs of headphones can, if necessary, be connected in parallel, across the output, provided that the isolating resistors (R53) are taken separately to each output jack. This will ensure that there are no problems if phones of dissimilar type of impedance are used. (See Fig. 10).

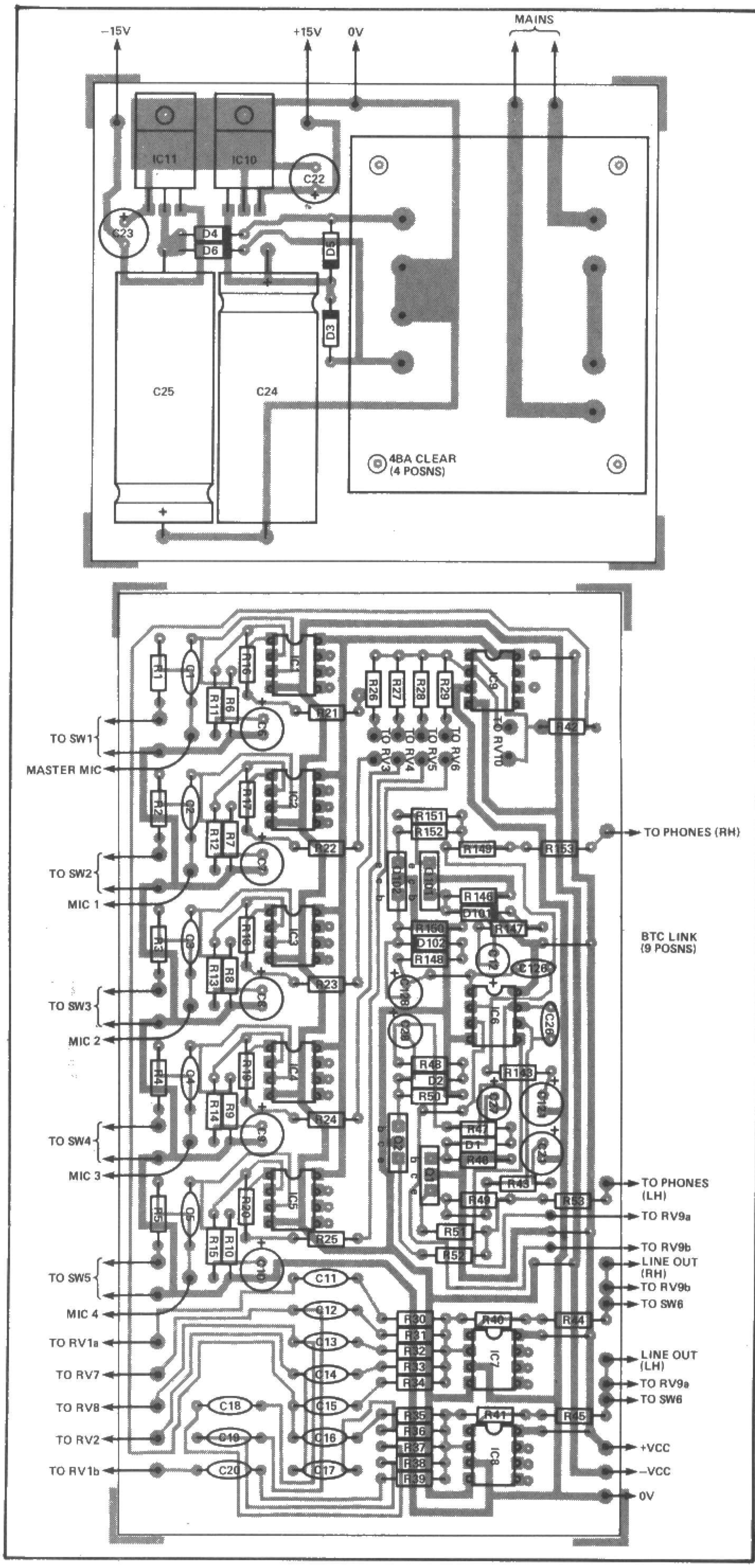
Mains Power Supply

Although the mixer unit can be used quite satisfactorily on a pair of 9V batteries, batteries are expensive and it is probable that it will be powered from the mains on most occasions. A very simple dual power supply, with a couple of voltage regulator ICs, was used on the prototype, as shown in Fig. 10.

Complete System

The whole unit is shown in Fig. 10 and fitted into a shallow sloping fronted box, 19" long, as shown in the photograph.

Since the specification to which this unit was built called for a stereo line input, as well as a pair of mono line inputs, a ganged 10K slider pot was used for RV1, while single slider units were employed for RV7 and RV8. The four main mic inputs are controlled individually by the slider pots RV3 to



RV6, with a master fader, RV10, controlling their overall level so that it can be faded down if, for example, a voice-over commentary is to be superimposed from the master mic.

A dual-gang slider pot, RV9, is used to control the volume level of the headphone outputs. Finally, an overriding stereo/mono control is provided by SW6, which simply parallels the two L and R outputs. In general, however, the unit is used in the stereo mode, with a stereo signal from the line input, over which the (mono) mic input voices appear on 'centre stage'.

No tone control facilities were required for the unit described in its initial emobidment (shown in the photograph), but subsequently a microphone input treble lift facility was added, to give greater clarity to some of the commentators' voices. This was done as shown in Fig. 7. The unit can completely replace the mic input shown in Fig. 4.

A more formal bass/treble-lift/cut tone control stage could be added, at pin 1 of ICs 7 and 8 in Fig. 10. The tone control circuit is shown in Fig. 8.

Full stereo system

It is very easy to organise this layout to provide more stereo input channels than the one stereo line input on the prototype.

This is done by taking each pair of inputs, say those from IC2 and IC3 (Fig. 10) and routing them to a pair of master fader stages, IC16a and IC16b, as shown in Fig. 12, and from there to ICs 7 and 8, as before.

The prototype unit was designed round TL071s or their higher specification equivalents, LF351. To enable the addition of extra facilities with relative ease, we have designed the board using TL072s (or LF353s) exclusively. Pads for the unused halves of the op amps can be found on the main PCB.

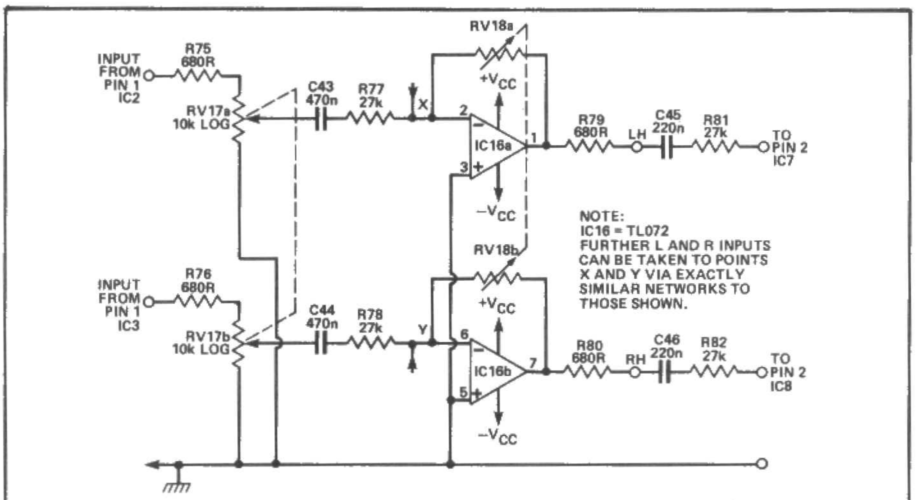


Fig. 12 Single stereo mic input arrangement using two mono input stages.

BUYLINES

There should be no problems with any of the components. Slider pots are widely available, but rotaries would suit. Wirewounds should be available from Watford, Maplin, Electrovalue or any regular ETI advertiser. Watford and Rapid also advertise 3 pole 4 way switches. 19" cases are available from Newrad or through our classifieds. The PCBs are available from the ETI PCB Service

PARTS LIST

MAIN BOARD

RESISTORS (all ⅓ watt unless stated)

R1,2,3,4,5	4k7
R6,7,8,9,10,16,17 18,29,20	100k
R11,12,13,14,15, 21,22,23,24,25,42, 44,45	680R
R26,27,28,29,30 31,32,33,34,35,36, 37,38,39,40,41	27k
R43	3k3
R46,49,50	10k
R47,28,	68R
R51,52	5R6 W/W
R53	10R W/W
RV1,9	10k log ganged sliders
RV2,3,4,5,6,7,8	10k log single sliders
RV10	47k single slider

CAPACITORS

C1,2,3,4,5,11,12, 13,14,15,16,17,18, 19,20	47μ 16V
C6,7,8,9,10,21	electrolytic 100μ 16V
C22,23	electrolytic
C24,25	2200μ 40V electrolytic
C26	10p
C27,28	22μ 16V electrolytic

SEMICONDUCTORS

IC1-6,8,9	TL072/LF353
IC10	7815
IC11	7915
Q1	BD537/BD239
Q2	BD538/BD240
D1,2	IN4148
D3,4,5,6	IN4002

MISCELLANEOUS

SW1,2,3,4,5,6	SPST switches
SW7	3 pole,4 way switch

Standard jack sockets (13 for main board configuration); PP9 battery clips (x2); 20-0-20 20VA transformer, TR1; 19" shielded cabinet.

(Note: R43-53, C21,26-28, Q1-2, D1-2 have corresponding components for the right-hand headphone amplifier. They are marked R143-153, C121, 126-128, Q101-102, D101-102 on the overlay diagram).

OPTIONAL BOARDS

RESISTORS (all ⅓ watt)

R54,64,66	100k
R55	1k0
R56	3k3
R57,62,67,74,75, 76,79,80	680R
R58	47k
R59,68	390R
R61	120k
R63,70	4k7
R65,71,73	2k2
R69,72	10k
R77,78,81,82	27k
RV11,12,13	10k log sliders
RV13	1k0 slider
RV15,16	100k sliders
RV18	47k ganged slider

CAPACITORS

C29,35,45,46	220n
C30,36	47μ 16V
C31,43,44	electrolytic 470n
C32	100μ 16V
C33,40,42	electrolytic 10n
C34	49n (22//27n)
C37	150n
C38	1μ0 ceramic
C39,41	47n

SEMICONDUCTORS

IC12-16	TL072/LF353

MISCELLANEOUS

Standard jack sockets as required.

(Note: R58-62, RV12 and C31-34 have corresponding components on the second channel of the RIAA equaliser board. They are numbered R158-162. RV112 and C131-134 on the component overlay. Likewise for components R69-74, RV15-16 and C38-42 whose second channel equivalents on the tone control board are marked R169-174, RV115-116 and C138-142).

ETI

UNIVERSAL EPROM PROGRAMMER MKII

Following on from last month's article which covered the theory and described an upgrade modification for existing programmers, Mike Bedford and Gordon Bennett describe an improved EPROM programmer for those building from scratch.

Unlike the MkI board, the MkII board has been made double sided to cope with the greater component density. In order to keep down the costs, plated through holes have not been used which means that the first task to be carried out in building this project is to insert pins into all the holes marked as such on the component overlay diagram, soldering them on both sides of the board. After having carried out this through pinning, the construction is quite straightforward. One point worth noting is that component leads are sometimes relied upon to make a connection from one side of the board to the other. This means that if a component lead passes through a hole with pads on both sides of the board, the lead should be soldered to them both.

The MKII board will be used in conjunction with a programming console housing a 28 pin ZIF (zero insertion force) socket and 2 LEDs (see photograph). The 2 LEDs on the console connect to the main board via a 3 or 4 core cable connected to SK4, the anodes being connected to A1 and A3, the cathode of the green LED to A2 and the cathode of the red one to A4. The ZIF socket is connected via a length of ribbon cable and a 28-pin DIL header to SK3 on the main board on a pin to pin basis. It should be noted that the DIL socket SK3 is the "wrong way round" with respect to all the DIL ICs on the board and accordingly care should be taken in plugging in the ribbon cable to the console. A 0.1uF capacitor should be connected between pin 28 and pin 14 on the ZIF socket.

Construction having been completed, it now remains to configure the board to reside at the required address and to set up the various Vcc and Vpp voltages. The addressing is determined by the links, LK1, which are wired into a

OOPS!

Since the appearance of last month's article, a problem has come to light regarding the programming of 27512 EPROMs.

The problem occurs when using the fast programming algorithm with the 27512 and results from the necessary sequence of operation adopted in the software. The $\overline{\text{OE}}$ line is held high until dropped to access the EPROM for reading and the $\overline{\text{CE}}$ line goes low as soon as the programming voltage is removed from the EPROM.

But on the 27512 the $\overline{\text{OE}}$ line is also the Vpp select line and so, although this line is set low by the software at the correct time, the combined line is still held high by the $\overline{\text{OE}}$ bit until it is time to read the EPROM. This is because the hardware combines these two lines in an OR gate. The effect is to hold the 27512 in programming mode for an extra 300 micro seconds at a time when, although the address and data busses should not be varying, the programmer itself is changing from program to verifying mode. It is quite possible that this would cause no ill effects, but it is undesirable and should be corrected.

A software solution would require a separate procedure for the 27512 in an already crowded EPROM, but a far simpler hardware modification is possible. It consists of the removal of two diodes and the substitution of a wire link for one of them. The diodes in question perform an OR function at the input of the active pulldown circuit which operates on pin 22 of the EPROM. They were put there to prevent high dissipation in the 120R resistor by removing the possibility of the software turning on both transistors simultaneously. No problems have been found using the existing software package without these diodes, and their absence has no effect upon the operation of the programmer with other EPROMs.

The modification is:

1) locate and remove the diode in the line from pin 14 of PIO 3 (IC7), the $\overline{\text{OE}}$ line;

2) locate and remove the diode in the line from pin 12 of PIO 2 (IC8), the Vpp select line;

3) replace this latter diode with a wire link.

This will prevent the $\overline{\text{OE}}$ line from influencing the pulldown of the Vpp/$\overline{\text{OE}}$ line.

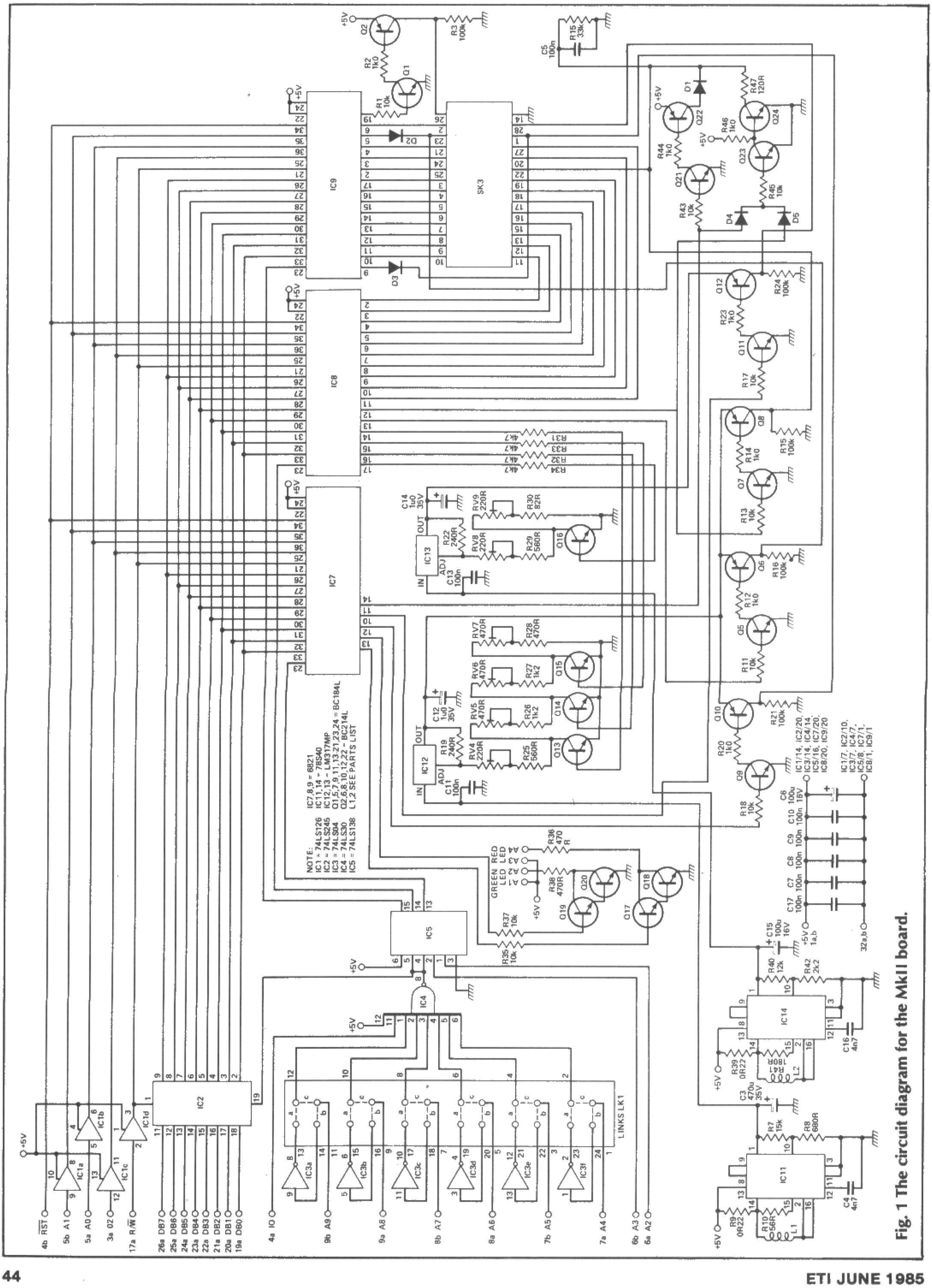


Fig. 1 The circuit diagram for the MkII board.

HOW IT WORKS

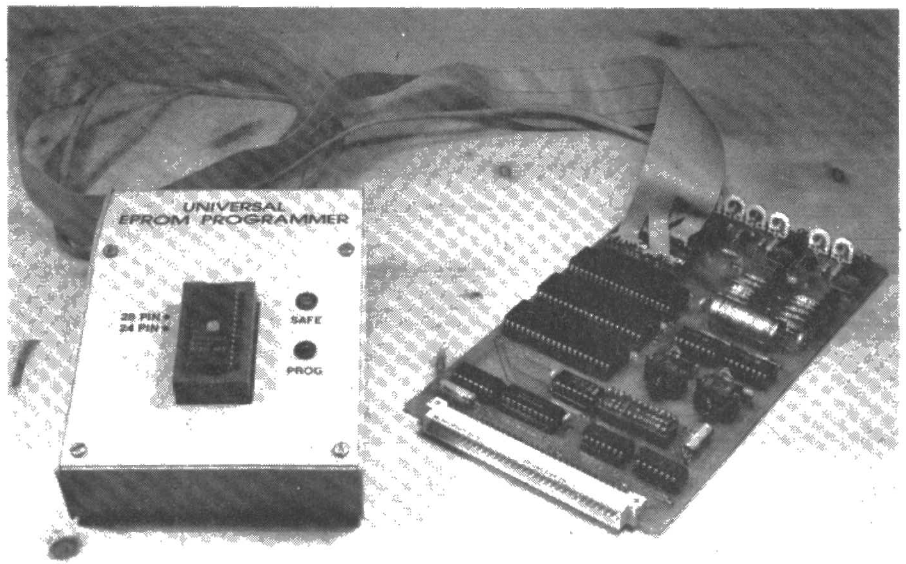
The components in Fig. 1, the circuit diagram of the Mk II board, have been numbered in such a way that they correspond to the component numbers on the Mk I and upgrade boards. Since a few components are removed from the Mk I board when the upgrade board is fitted there will be some gaps in the component numbers on the Mk II programmer. Once this is realised, this arrangement should cause less confusion than if components with the same function were to have different numbers in the two configurations.

The heart of the circuit is three 6821 PIAs which control all the programmer functions. These are interfaced in a standard way to the Tanbus signals on the edge connector. IC1 and IC2 buffer various signals to ensure that only 1 TTL load is applied to a bussed signal and the combination of IC3, IC4, IC5 and the links control the addressing and allow the board to be located within any 16 byte block in the I/O area. The Vpp supply is generated at +30V by the circuitry associated with IC11 which is a step-up circuit and is then regulated to the required level (+25V, +21V, +12.5V or +5V) by a programmable LM317MP regulator, IC12. Since the voltage output of an LM317MP is determined by the value of the resistor between the adjust pin and 0V, the Vpp level is controlled by switching the transistors Q13, Q14 and Q15 from PIA IC8 so cutting out portions of the resistor chain.

A similar approach is used to generate Vcc, IC14 generating +8V and IC13 regulating to +5V or +6V as controlled from IC8. Where a pin on the EPROM (which is connected to SK3) requires a TTL signal level it is connected directly to an output of one of the PIAs. Where a Vpp or Vcc level is required, however, a NPN/PNP transistor pair is used to carry out the switching under the control of a PIA output. In all such cases the transistor pair must be connected to a PIA 'B' port, these having totem-pole outputs which can supply sufficient current to switch a transistor.

The signal level on some pins may be either TTL or Vpp, depending on the EPROM type. In such cases, both signals are connected to the appropriate pin but the two are isolated from each other by use of a diode on the TTL signal line. When a TTL level is isolated by a diode, this is driven by a PIA 'A' port since these outputs have resistive pull-ups and will give a level that is high enough to be a true TTL high even after allowing for the voltage drop across a germanium diode.

The data sheets for the 2732 call for a 100uF capacitor (C5) connected between pin 22 and 0V while programming. This will suppress spikes on the Vpp supply which could be detrimental to the EPROM. Unfortunately the provision of such a suppression capacitor will have the result of slowing down logic edges when a TTL level is applied to pin 22. For this reason, the time constant is kept to a minimum by using Q21 and Q22 as a high current OE drive and Q24 to provide a logic low bypassing C5. Transistor Q23 turns on Q24 when neither the OE nor the Vpp signal driving EPROM pin 22 is present. To complete the circuit description, Q17, Q18, Q19 and Q20 form two darlington pairs which are used to drive a pair of LEDs on the programming console.



Voltage required	ZIF pin to monitor	Register address offset	Value to write to register (HEX)	Potentiometer to adjust
—	-	0B	00	—
—	-	0A	FF	—
—	-	0B	04	—
—	-	0A	03	—
—	-	07	00	—
—	-	06	FF	—
—	-	07	04	—
+5V	1	06	10	RV4
+12.5V	1	06	40	RV5
+21V	1	06	20	RV6
+25V	1	06	00	RV7
+5V	28	06	80	RV8
+6V	28	06	00	RV9

Table 1 The set-up arrangements for monitoring and adjusting program voltages.

PARTS LIST

Programming Console

- 1 x Instrument case with sloping top
- 1 x 28-pin DIL Zero Insertion Force socket
- 1 x Length of 28-way ribbon cable
- 1 x 28-pin DIL header
- 1 x 100 μF ceramic capacitor
- 1 x Red LED
- 1 x Green LED
- 1 x Length of 4-way cable

DIL header and plugged into the appropriate DIL socket. The board occupies a 16-byte block within the 1K Tanbus I/O space, the start address relative to the start of this I/O area being 16 times the binary number represented by the block of links. The examples of link selection in Fig. 2 should make it quite clear how to set up any required addresses. The MkII board has been designed with the voltage setting potentiometers placed along the edge of the board so that they may be easily adjusted once the board has been positioned in a card frame. The voltages may now be monitored on the programming console and adjusted, using the potentiometers, by writing values to the programmer registers using the system monitor (or a BASIC program). Table 1 shows the requisite programming voltages, associated pins, registers, data and potentiometers.

MKII UNIVERSAL EPROM PROGRAMMER : HARDWARE SPECIFICATION

Devices supported	: 2758, 2716, 2516, 2732, 2732A, 2532, 68732, 2764, 2764A, 2564, 68764, 27128, 27128A, 27256, 27512, 27513,2816, 2864
Device selection	: Software controlled
Programming methods	: Intelligent or fixed pulse
Vpp voltages	: +25V, +21V, +12.5V
Vcc voltages	: +6V, +5V
Indicators	: 2 LEDs on console
PCB format	: 8" x 4½" with indirect connector
Interface	: Tanbus (6502, 6800, 6809 adaptable)
Power requirements	: +5V @ 900mA
Memory space occupied	: 12 bytes selectable to any 16 byte boundary within the I/O area
System requirements	:RAM — 1K for 2758 to 32K for 27256, 27512* and 27513* plus small amount for support firmware. (*:these EPROMs programmed in 2 segments) EPROM — 2K utilities package

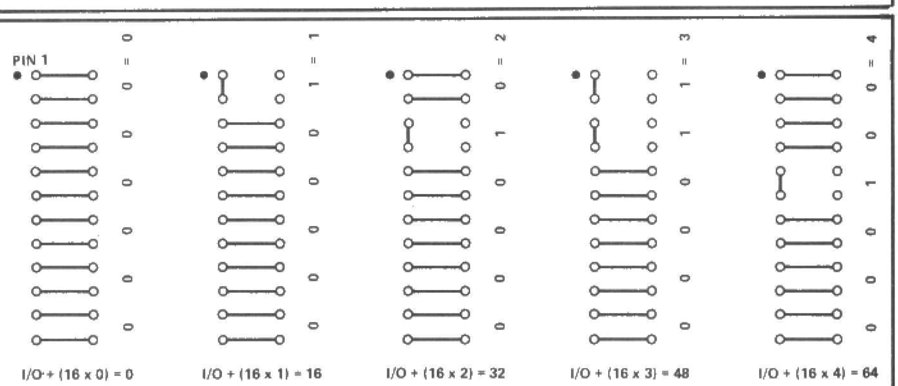
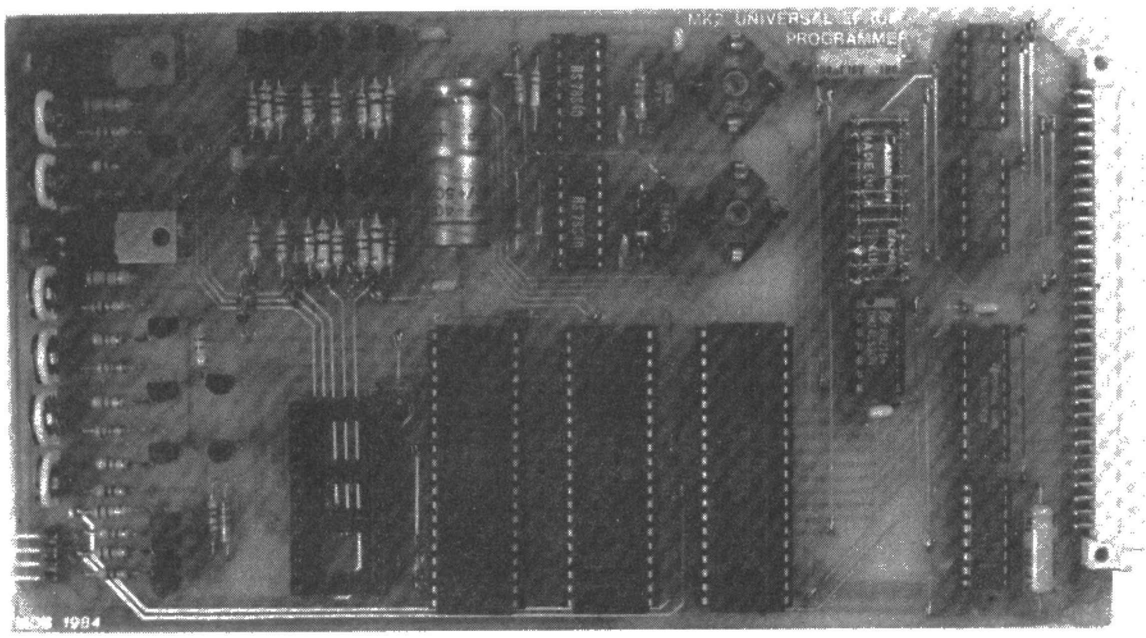


Fig. 2 LK1 address link selection for the MkII board.



PARTS LIST

RESISTORS (All ¼W, 5% unless stated)

R1,11,13,17,18,35, 37,43,45	10k
R2,12,14,20,23,44, 46	1k0
R3,15,16,21,24	100k
R7	15k 2%
R8	680R 2%
R9,39	OR22 W/W
R10	56R, 1W
R41	180R, 1W
R41	180R, 1W
R19,22	240R
R25,29	560R
R26,27	1k2
R28,36,38	470R
R30	82R
R31,32,33,34	4k7
R40	12k
R42	2k2
R47	120R ½W
RV4,8,9	220R vertical miniature preset
RV5,6,7	470R vertical miniature preset

CAPACITORS

C5,7,8,9,10,11,13, 17	100n Ceramic
C3	470μ 35V axial electrolytic
C4,C16	4n7 ceramic
C6,C15	100μ 16V axial electrolytic
C12,C14	1u0 35V tantalum

SEMICONDUCTORS

IC1	74LS126
IC2	74LS245
IC3	74LS04
IC5	74LS138
IC7,8,9	6821 (or 6520 etc)
IC11,14	78S40
IC12,13	LM317MP
Q1,5,7,9,11,13,14, 15,16,17,18,19, 20,21,23,24	BC184L
Q2,6,8,10,12,22	BC214L
D1,2,3,4,5,	OA91

MISCELLANEOUS

L1	34 turns 24 SWG wire on RM6 pot core (AL=250)
L2	13 turns 22 SWG wire on RM6 pot core (AL=250)
SK3	28 pin DIL socket
Connector A	4 way 0.1" pitch right angled molex connector.
Links	Links wired on 24-way 0.3" width DIL header plugged into DIL socket (use 16-way +8-way)

PCB; 1 x 32-way A+B DIN Euro connector, male angled pins.

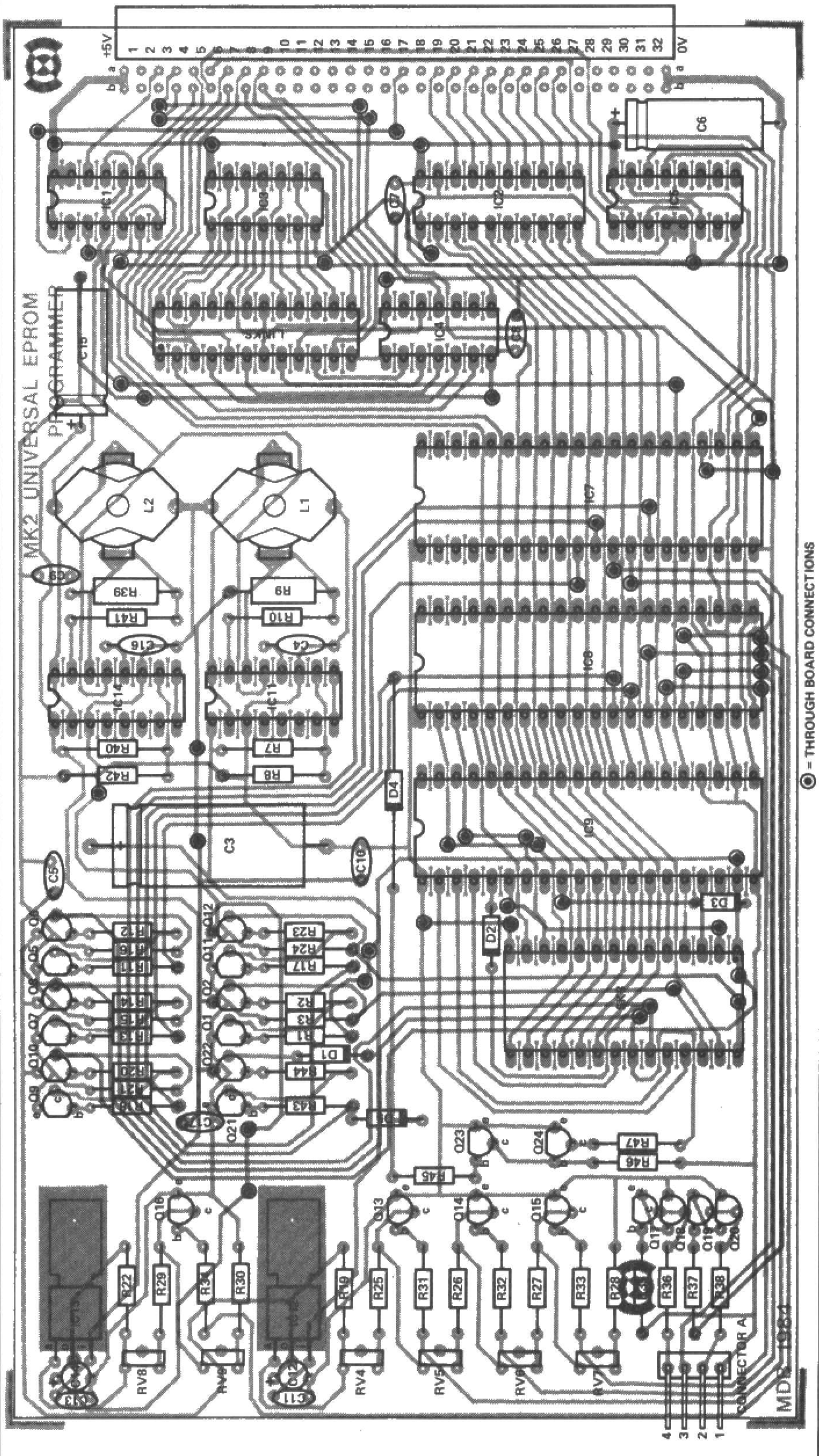


Fig. 3 Overlay diagram of the complete MkII board.

NOTE: Component numbering conforms to original project. R4, R5, R6, C1, C2, IC6, IC10, Q3 and Q4 have not been accidentally omitted. The numbers refer to components which have been removed from the original board in the course of producing the MarkII board.

To be continued.

ETI

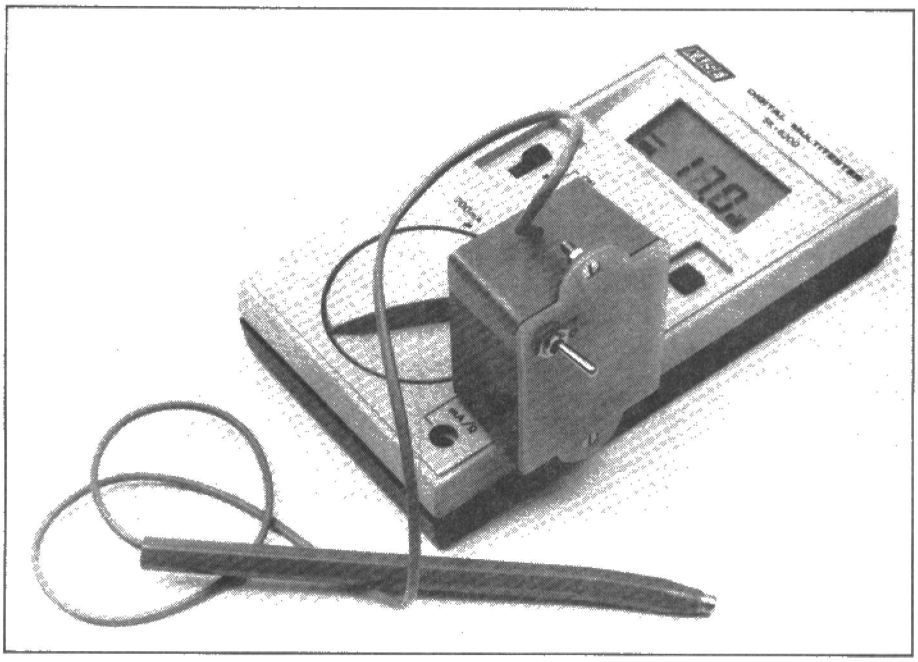
THE HEAT PEN

Geoff Phillips' project may make your blood boil or leave you cold — either way you can measure the temperature with this simple digital voltmeter add-on.

The Heat Pen is a low cost temperature probe that transforms a standard DVM into a digital thermometer. Just plug the Heat Pen into any digital voltmeter, place the tip onto a surface, and the DVM shows its temperature directly in °C. Its range is from -50 to +150°C.

Thermocouples are messy: they require cold junction compensation and scale conversion. Stick on labels have their uses but they are expensive and can only be used once. The Heat Pen is an inexpensive solution to your temperature measurement problems.

Temperatures of power transistors can be measured easily. Balance your central heating radiators by measuring inlet and outlet temperatures. Take your own temperature by placing the Heat Pen under your tongue. The uses are endless.



A semiconductor temperature sensor is used as the probe tip. It gives a nominal 1μA per Kelvin. This is converted to 10mV per Kelvin. A bandgap voltage reference is amplified to 2.73V. This is subtracted from the voltage signal derived from the probe tip so that the remaining voltage is equivalent to 10mV per °C. Low power semiconductors are used making the quiescent current drain of the Heat Pen less than 1mA.

Nearly all DVMs are fitted with 4mm input sockets which are pitched ¾" apart. The Heat Pen's PCB, as well as housing the circuitry, also has two 4mm plugs firmly fitted at the ¾" pitch. The PCB, along with a PP3 battery fits neatly into a smart plastic potting box. The probe is mounted in a ball point pen casing and is connected to the PCB via a screened cable.

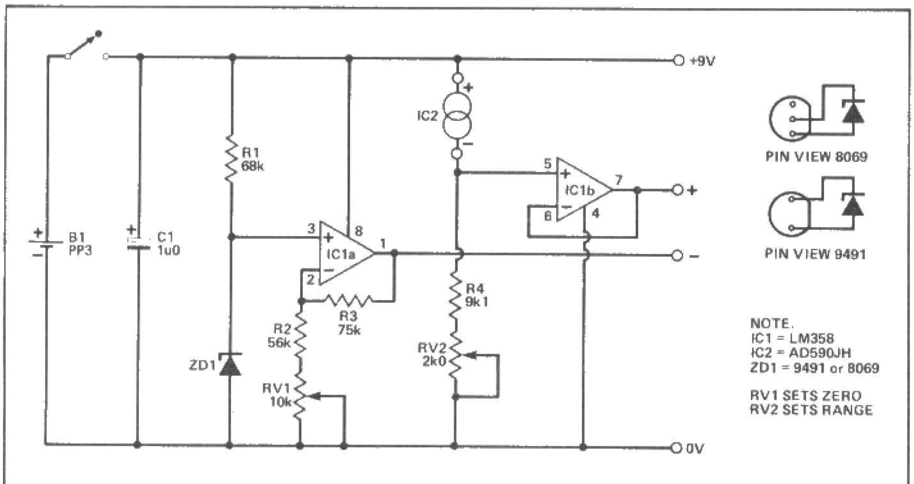


Fig. 1 Circuit diagram of the heat pen.

Construction

Fit the resistors, capacitor then IC1 and ZD1 to the PCB. No special precautions are required. Remove the plastic casing from the two 4mm terminals and using a junior hacksaw, cut 11mm off the hexagonal sections of the terminals so that approximately 12mm remains. The terminals already have one hole drilled in the hexagonal section. Ideally a second hole should be drilled 8mm from the first. If you have metric taps, drill these holes for an M3 tap and then tap out the holes. Secure the two 4mm terminals to the PCB with M3x6mm screws. If you cannot lay your hands on metric taps then the terminal may be fixed to the PCB by passing short lengths of heavy gauge copper

wire through the holes and soldering the wires in place. The wires are then passed through the holes in the PCB and soldered in place.

Solder the -ve lead of the PP3 battery clip to the 0V terminal of the PCB and solder a 2" lead to the +9V terminal. Solder the core of the screened lead to the PCB and the screen to +9V terminal. The case must now be prepared for the fitting of the PCB.

First of all it is necessary to make a cover for the potting box. This may be made from glass fibre sheet, paxolin, or plastic sheet. Use the potting box as a template and draw around its shape on the plastic sheet with a scriber. Cut out the shape with a hacksaw. After dressing up the cover with a file, temporarily clamp it to the potting box and drill two M4 clear holes through the lugs of the box and cover. Drill and file a hole in the cover for the on/off switch.

The hole will have to be carefully positioned so that the switch does not foul the PP3 battery when the unit is assembled. Fit the switch to the cover. Drill two 4.7mm holes in the side of the potting box (Fig. 2) to allow the 4mm terminals to protrude from the box and one small hole in the opposite end of the box for the screened cable.

Tie a knot in the screened cable about 25mm away from the PCB and then pass the cable through the small hole in the box. Pass the two 4mm terminals on the PCB through the two holes in the box and continue to pull the screened cable through the hole until the PCB is positioned at the bottom of the box.

Pass the screened cable through the empty ball point pen casing and solder it carefully to the temperature sensor AD590JH. Connect the screen to the +ve lead and the case lead of the sensor. Connect the core to the -ve lead of the sensor. Insulate the leads from each other with sleeving then the sensor can be positioned at the tip of the pen casing and secured with adhesive. Solder the +ve lead of the PP3 clip and the +ve lead from the PCB to the two switch terminals. The Heat Pen is now ready for calibration.

HOW IT WORKS

Fig. 1 shows the circuit diagram of the Heat Pen. IC2 is a semiconductor temperature sensor which gives a nominal 1µA per Kelvin. This is converted to 10mV per Kelvin by R4 in series with RV2. Thus at 0°C RV2 is adjusted for 2.73V at the output of the buffer amplifier IC1b. ZD1 is a bandgap voltage reference which gives a nominal 1.225V. IC1a is a non-inverting amplifier whose gain is adjusted by RV1 to give 2.73V at pin 1. Thus the differential voltage between the two op-amp outputs is equal to 10mV per °C. The heat pen is plugged into a DVM set to the 100mV scale and a reading in °C is given. (The decimal point has to be implied by the user).

PARTS LIST

RESISTORS (All 1% metal film)	
R1	**68k**
R2	**56k**
R3	**75k**
R4	**9k1**
RV1	**10k horizontal lin pre-set**
RV2	**2k horizontal lin pre-set**
CAPACITORS	
C1	**1µ0 16V axial electrolytic**
SEMICONDUCTORS	
IC1	**LM358N**
IC2	**AD590JH**
ZD1	**TSC9491BJ or ICL8069DCZR or any 1.225V bandgap voltage reference with tolerance ± 2% and temperature coefficient of 100ppm/degC**

MISCELLANEOUS
PCB; Potting box type GPL2; 4mm terminals; PP3 battery clip; small on/off toggle switch; PP3 battery; ball point pen casing.

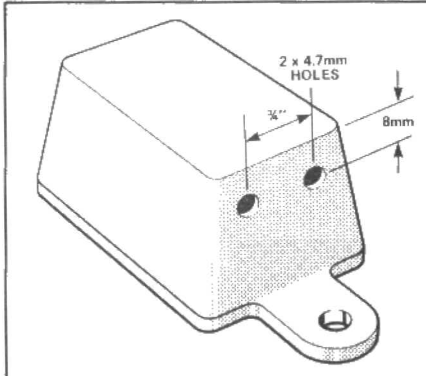


Fig. 2 Case details for the heat pen.

Calibration

A crude but effective way of calibrating the Heat Pen is in iced water. Ideally the water should be distilled and free from contaminants which may alter the freezing point temperature. It is important to ensure that water does not penetrate the leads of the temperature sensor as it will cause a leakage current to flow and thus give an erroneous reading. Therefore place the heat pen probe in a plastic bag and place in a vessel of iced water. Switch on the Heat Pen and with your DVM monitor the voltage at pin 7 of IC1 with respect to 0V. Adjust RV2 for ~~2.37V.~~ 2·73V (X)

Now plug the Heat Pen into the DVM. Adjust RV1 until 0.00V is obtained. The unit is now calibrated to 0°C. Cut out a piece of foam rubber to fit on top of the PCB in the box. This is to prevent the battery casing from short circuiting the components, and also to prevent everything from rattling around inside the box. Fit the battery on top of the foam rubber and fit the cover with its switch to the box and secure with two M4 nuts and bolts.

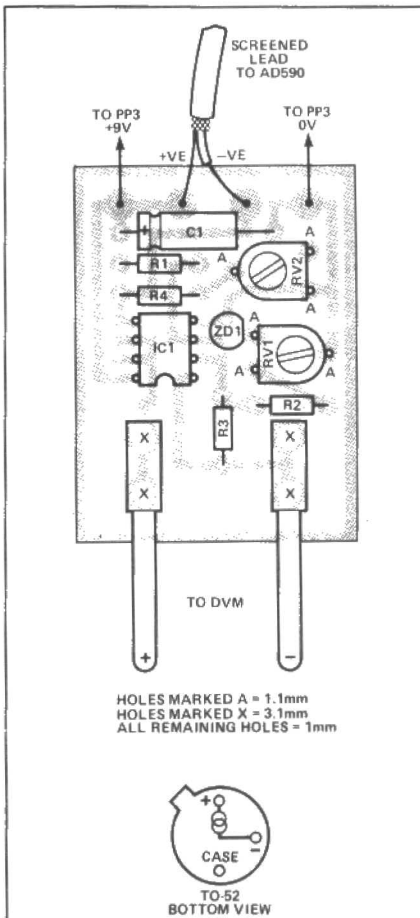


Fig. 3 Overlay diagram and pin-out of the AD590 temperature transducer.

BUYLINES

A complete kit of parts (excluding the PP3 battery) is available from: G.P. Electronic Services, 87 Willowtree Avenue, Durham, DH1 1DZ. The cost is £8.75 inc VAT and postage for the complete kit or £1.75 for the PCB only. Note that the PCB will not be available from our PCB Service.

(X) = ERROR / CORRECTION

ETI

OOPS! FROM P. 62 ETI FEB 1986

SERVICE SHEET

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We receive a very large number of enquiries. Would prospective enquirers please note the following points:

- We undertake to do our best to answer enquiries relating to difficulties with ETI projects, in particular non-working projects, difficulties in obtaining components, and errors that you think we may have made. We do not have the resources to adapt or design projects for readers (other than for publication), nor can we predict the outcome if our projects are used beyond their specifications;
- Where a project has apparently been constructed correctly but does not work, we will need a description of its behaviour and some sensible test readings and drawings of oscillograms if appropriate. With a bit of luck, by taking these measurements you'll discover what's wrong yourself. Please do not send us any hardware (except as a gift!);
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OOPS!

Corrections to projects are listed below and normally appear for several months. Large corrections are published just once, after which a note will be inserted to say that a correction exists and that copies can be obtained by sending in an SAE.

CMOS Tester (August 1984)
C3 and C2 are reversed on the overlay: C3 is the electrolytic and C2 the polyester. R33 is 100K not 1M as given in the parts list, and RV1 is a 1M horizontal skeleton preset. R1-16 are two, eight-resistor SIL packages, the component labelled C14 on the overlay is SK1, and the connections to D2 shown in Fig. 3 are reversed. On the circuit diagram, the eight lines connecting SW9-16 to the inverters are shown in reverse sequence. Some of the inverters have been given the wrong designations; the correct sequence, reading down from the top, is:- IC1f, IC2a, IC2b, IC1e, IC1d, IC1c, IC1b, IC1a, IC2c, IC2d, IC2e, IC3d, IC3a, IC3b, IC3c, IC2f. Finally, the pin numbers are missing from ICs 3e and f; the input of IC3e is pin 11 and its output pin 12, and the input of IC3f is pin 14 and its output is pin 15. The PCB is correct in all respects. X

AM/FM Radio (November 1984)
In Fig. 2, the oscillator and IF sections should be shown connected to ground; the PCB is correct. In Fig. 4, C31 should be 10n to give the 75us deemphasis shown in Fig. 3, but 4n7 has been found to give a brighter midrange. R38 in Fig. 5 should, of course, be 820k rather than 280k and it and the bottom end of C38, C44 etc should be shown connected to ground. In the construction section on page 25, four pieces of 8mm plywood are mentioned but in fact only three are needed — the fourth side is the front panel. See also the note in December News Digest regarding availability of the inductors.

Digital Control Port (November 1984)
The second sentence in the "Testing" section on page 30 should include the words 'without any ICs in place'. In the second paragraph of that section, the check for +5V should be made on pin 3 of IC101, not IC1. At the bottom of the first column on page 31, the last sentence should finish with B3 = 0.

Video Vandal (November 1984)
In Fig. 8 on page 54, R16 and R17 should be shown connected to the base of Q4, and C12 and SW2 should be in the D output line rather than the OV line. It may also be beneficial to add a diode across R3 with its anode connected to the slider of RV1. In Fig. 10, R52 and LED2 are shown connected across the +12V supply but it is better to place them across the −12V supply so as to even-up the dissipation in the ICs.

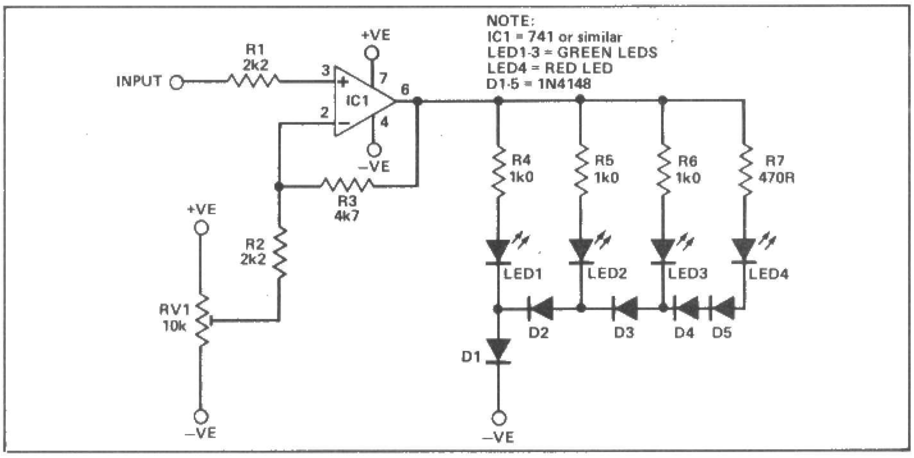
Digital Delay Line (December 1984 - January 1985)
In Fig. 6 on page 21 of the December issue, C19 and C20 are both 100uF. In Fig. 8 on page 62 of the January issue, C3 should be marked 33p. On the overlay diagram (Fig. 9, p.64), R37 is missing and should be connected between pin 3 of IC9 and the 0V line; R20 is missing and should be located in the holes immediately to the left of R18; R50 is missing and should be connected between pins 1 & 2 of IC14. Some components on the overlay have also been wrongly numbered:- C20 should be marked C19 and C21 should be marked C20; R12 (between ICs 5 & 6) should be marked R22; R48 should be R44, R49 should be R45, R57 should be R46, R51 should be R47, R50 should be R48, and R47 should be R49. The unmarked capacitor directly above what is now C19 is an un-numbered 100n ceramic. C30 does not appear on any diagram or parts list and this is correct. X

"Sonneti" Combo (March 1985)
The foil pattern on the overlay diagram has been shown as though from the copper rather than the component side. The foil is correctly shown on the Foil Patterns page from the copper side. X

VCDO (March 1985)
RV2 should be 10k (right in parts list, wrong on circuit diagram).

X = NOTES WITH MAGAZINES CONCERNED

TECH TIPS



Budget VU Meter

J. Green
London

The circuit uses three or more green LEDs and one red LED to indicate the level of a varying input signal. Each LED is connected to a different point on a chain of diodes and will only light up when the applied voltage exceeds the combined conduction threshold of all the diodes connected between its cathode and the negative rail.

About 5.2V is needed to light all the LEDs in the chain, and this is achieved by using an operational amplifier arranged to give a gain of 3.5. This is sufficient to light the red LED from a standard 0dB signal input. RV1 sets the gain of the op-amp and is adjusted so that the red LED just lights up at the required level.

The circuit works well with a supply of ± 5V, but if you wish to use more LEDs in the chain the supply voltage will have to be increased and the value of R3 raised to increase the gain of the op-amp. An op-amp with a higher current rating may also be required.

Divider Output	hours	X mins	secs
2★★6	0.00036	0.0213	1.28
2★★7	0.00071	0.0427	2.56
2★★8	0.00142	0.0853	5.12
2★★9	0.00284	0.1707	10.24
2★★10	0.00569	0.3413	20.48
2★★11	0.01138	0.6827	40.96
2★★12	0.02276	1.3653	81.92

Cheap Hour Counter

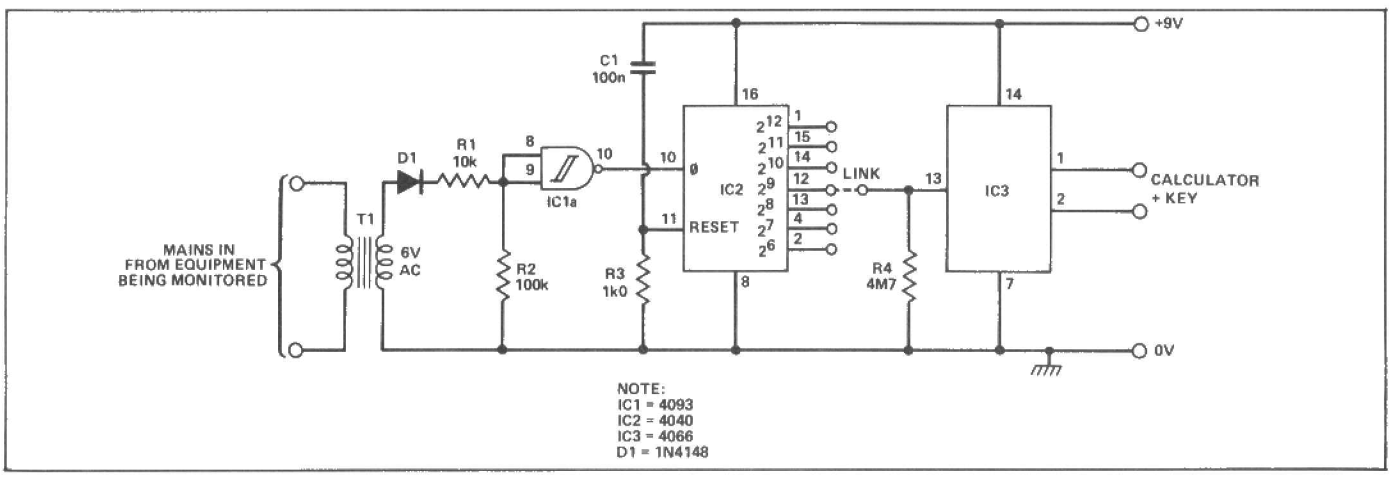
P. Roch
Luxembourg

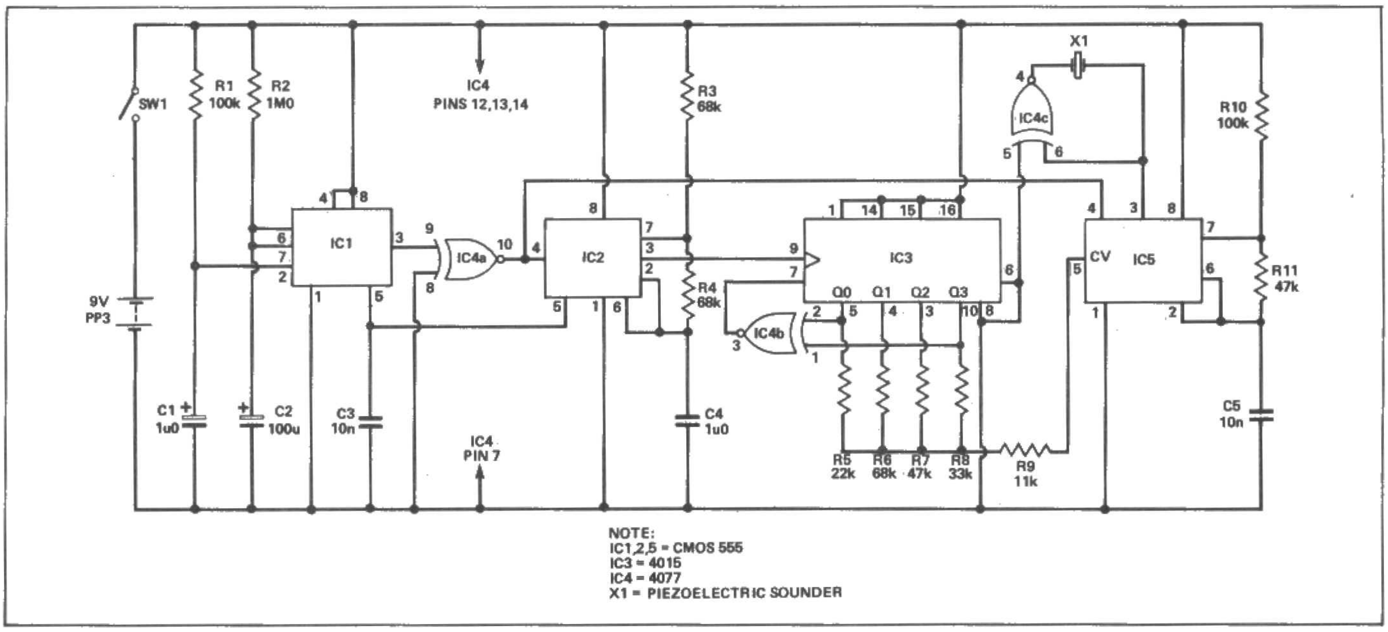
It is often useful to be able to measure the period of time for which a piece of mains-powered equipment has been in use, but the elapsed hour counters sold for this purpose are quite expensive. This circuit, which was originally designed for use with a central heating burner, uses a redundant calculator as the display and can be built very cheaply.

The circuit works by taking a 50Hz signal from the piece of equipment being monitored and divides this to drive the '+' key of a calculator. The calculator used must have the facility whereby an entered number, X, is incremented by each push of the '+' key to become 2X, 3X, 4X, etc. Most cheap calculators have this function.

The 50Hz signal is obtained from a small 6V transformer whose primary is connected in parallel with the mains supply to the equipment being monitored. The AC signal is rectified by D1 and then squared-off by the Schmitt trigger, IC1a. The resulting waveform is fed to the twelve stage ripple counter IC2, and the divided output then used to operate the bilateral switch, IC3. The switched output of this IC is connected across the '+' key of the calculator.

In use, the appropriate value of X for the readout required is keyed into the calculator and the 50Hz signal applied to the input. Values of X to give displays in hours, minutes and seconds are given in the table for various divider outputs.





Annoying Alarm

P. Cooper
London

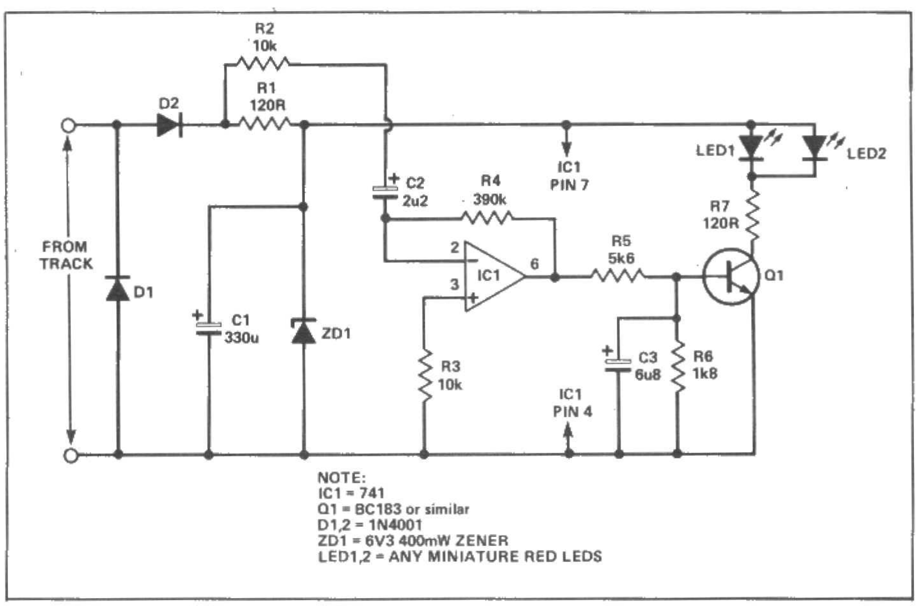
This circuit was designed to drive a computer maniac away from his machine in time for meals and emits an annoying pseudo-random sequence of tones about two minutes after being switched on. The prototype was arranged to be switched on by the removal of a jack plug so that it could not easily be disabled once activated.

A two minute delay is produced by monostable IC1, which is triggered by C1 when power is applied. IC1's output is inverted to give an active high enable signal which allows astables IC2 and IC5 to run after the delay. IC2 clocks a 4-bit shift register (IC3) at about 5 Hz while IC5 generates an audio tone whose frequendy is modulated by IC3's outputs and R1 to R5. The first and last outputs of the shift register are Exclusive-NOR'ed and the result is fed to the data input to produce the pseudo-random code. The two terminals of the piezoelectric buzzer are driven in antiphase to increase sound output.

The resulting alarm is very annoying, as people present during its development will testify!

Slot Car Brake Lights

M. Kendall
Fleet,
Hampshire



This circuit may be fitted to most small slot-type racing cars and drives two red LEDs mounted at the back of the car. The LEDs are automatically illuminated whenever the slot-car slows down, giving a realistic imitation of the action of car brake lights.

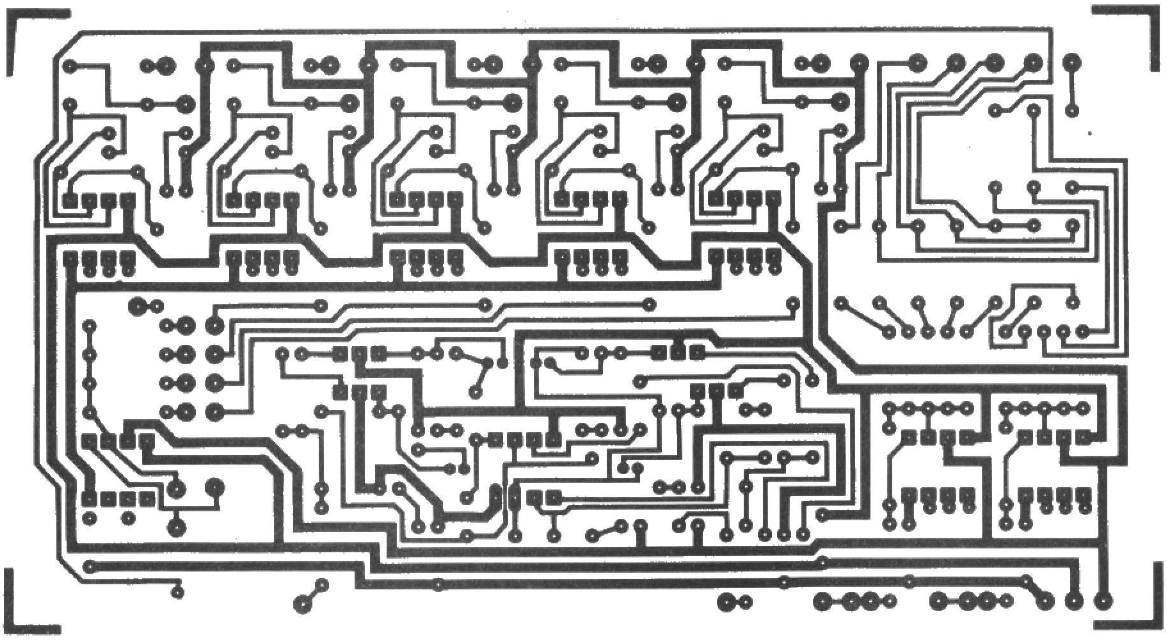
The circuit is based around IC1 which is connected as a differentiator. It monitors the voltage being supplied to the car and turns on Q1 as this falls. D2, ZD1, R1 and C1 provide a regulated supply for IC1. D1 removes any negative going spikes produced by the motor. With a constant voltage across the track the output of IC1 sits at about 2V DC, with a large AC content caused by spikes from the motor. R5 and R6 form a potential divider which holds Q1 just off under these conditions and C3 removes most of the AC. When the voltage across the track drops and the car slows down, the output of the IC rises to around 4V increase sound output.
and Q1 switches on, lighting the LEDs.

If the LEDs tend to flicker when driving at constant speed C3 can be usefully increased; size is the important consideration here, so use a tantalum capacitor.

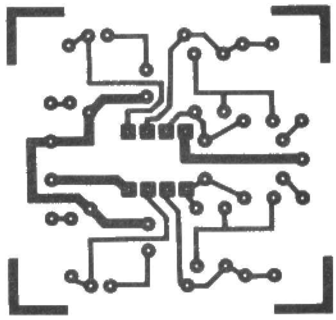
The circuit has been fitted in Scalextric rally cars and works well in practice.

ETI

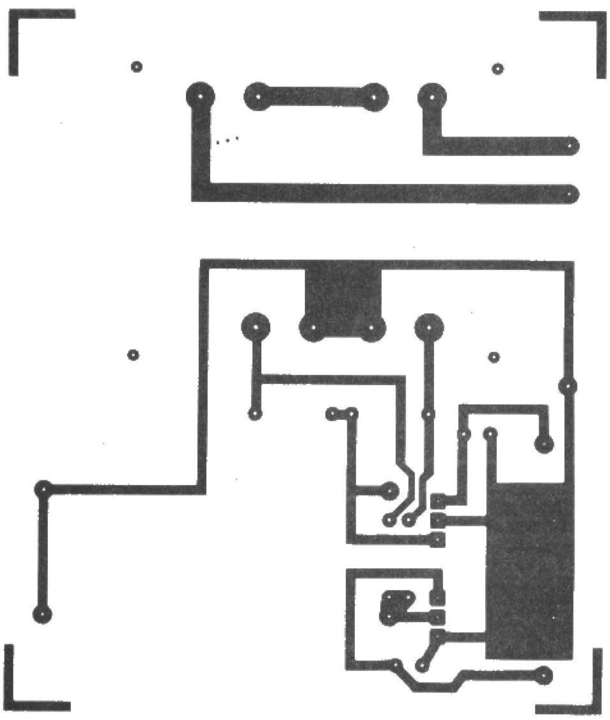
FOIL PATTERNS



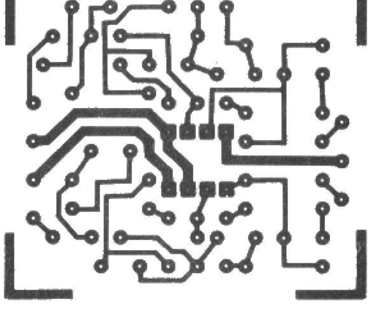
The pattern for the main board of the audio mixer.



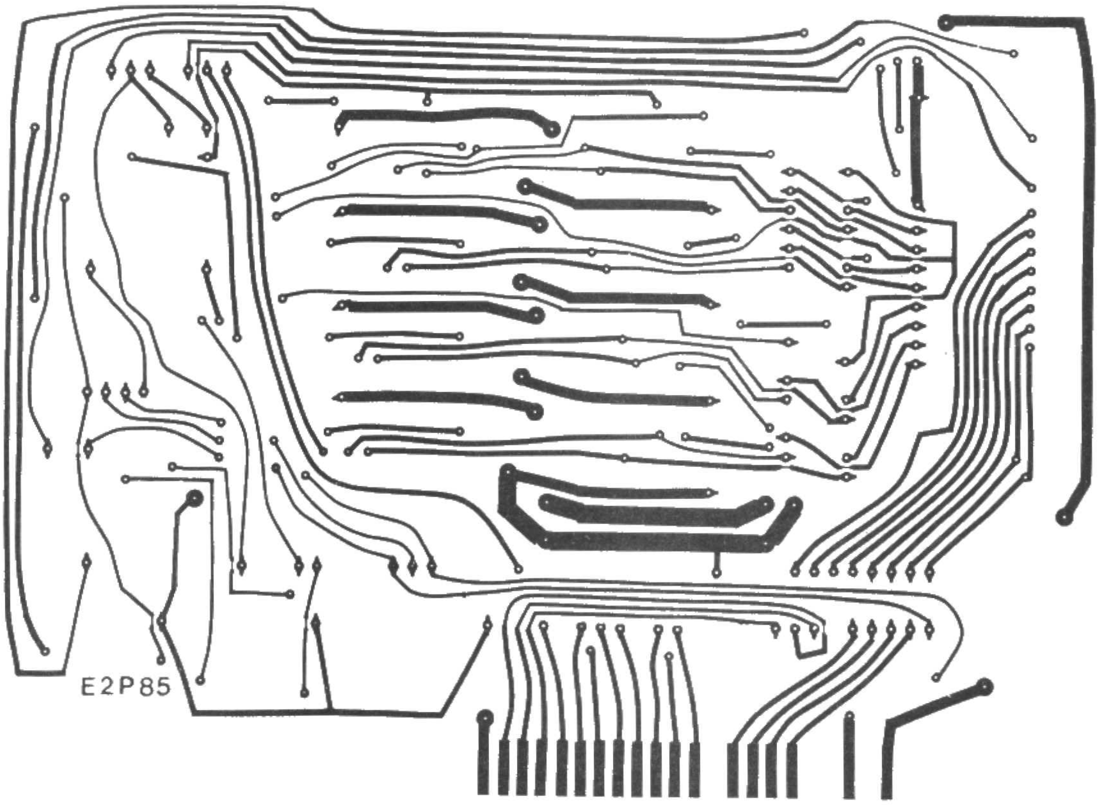
The audio mixer RIAA input stage board.



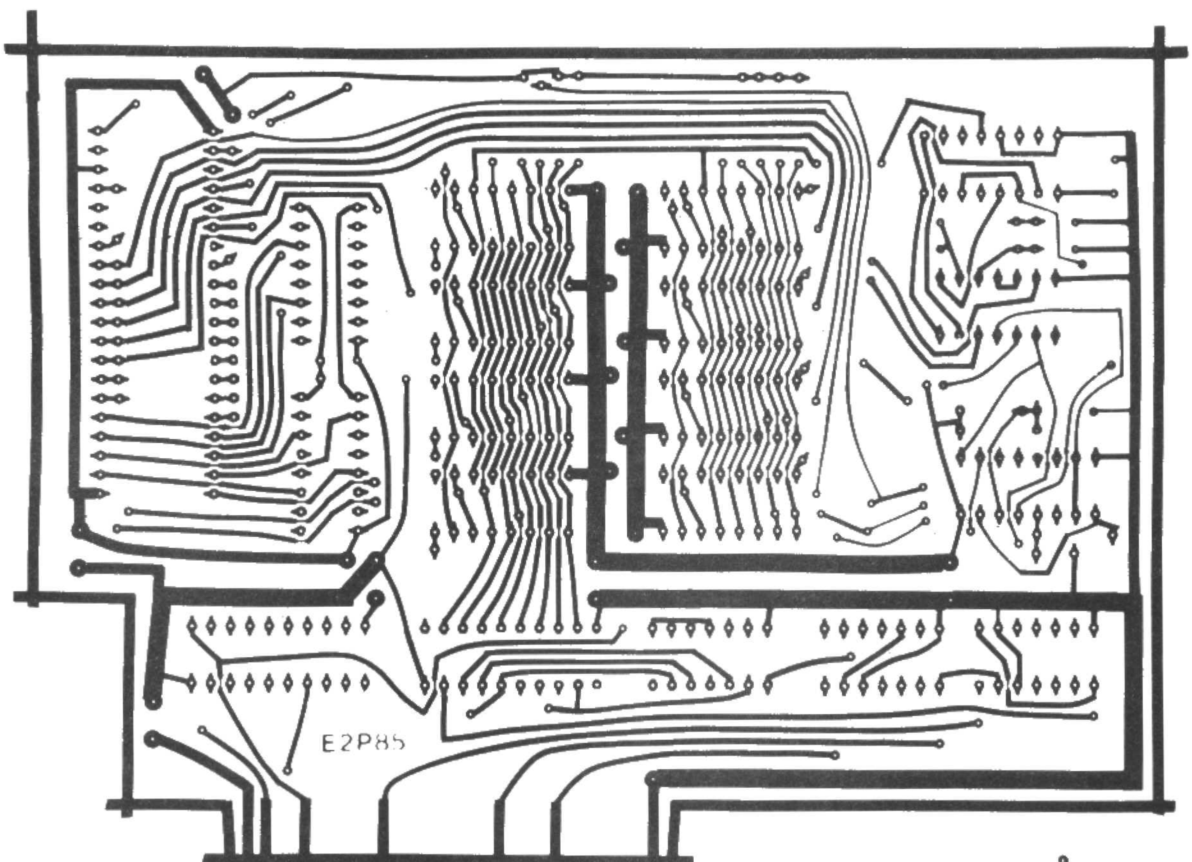
The power supply board for the audio mixer.

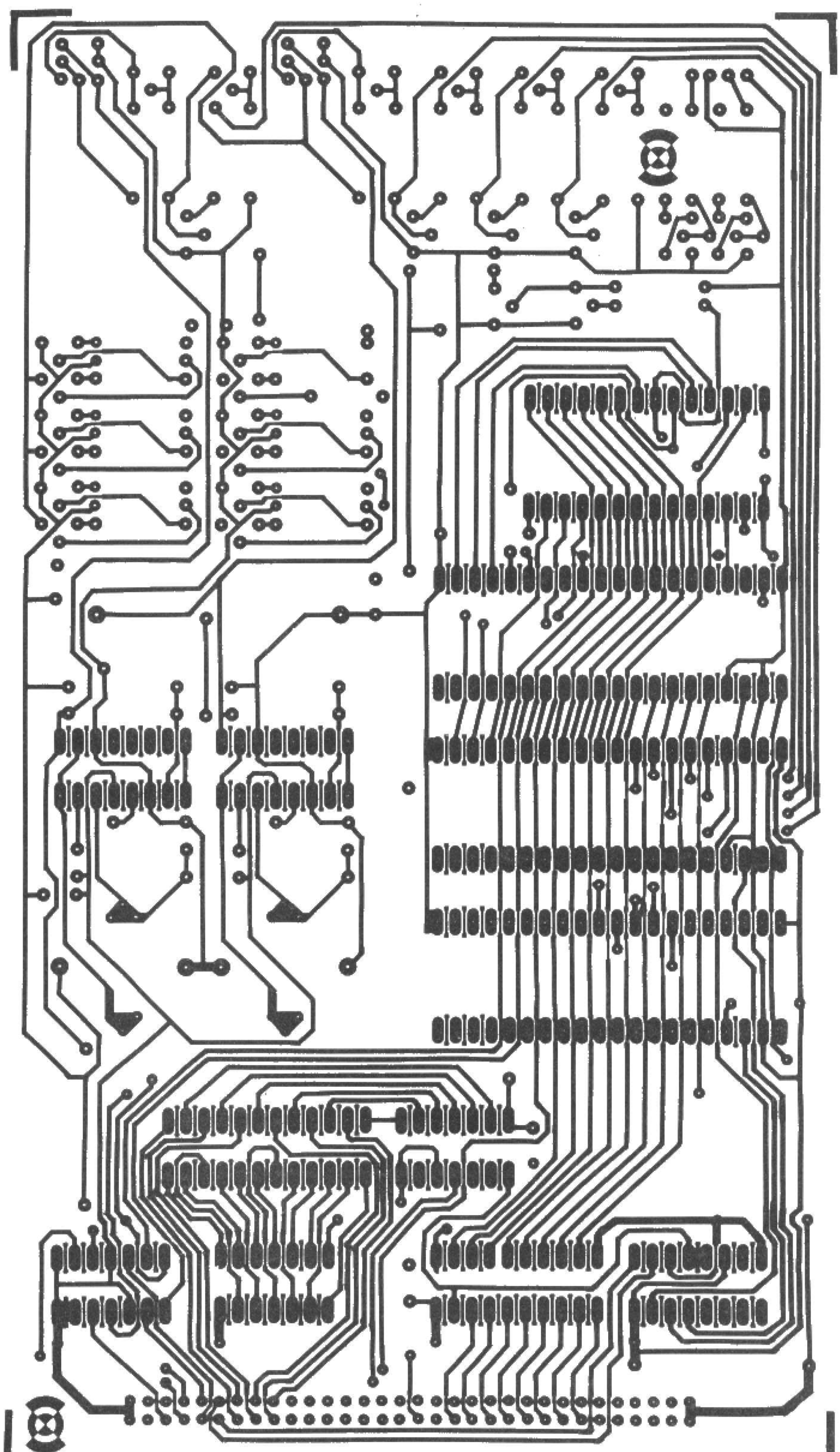


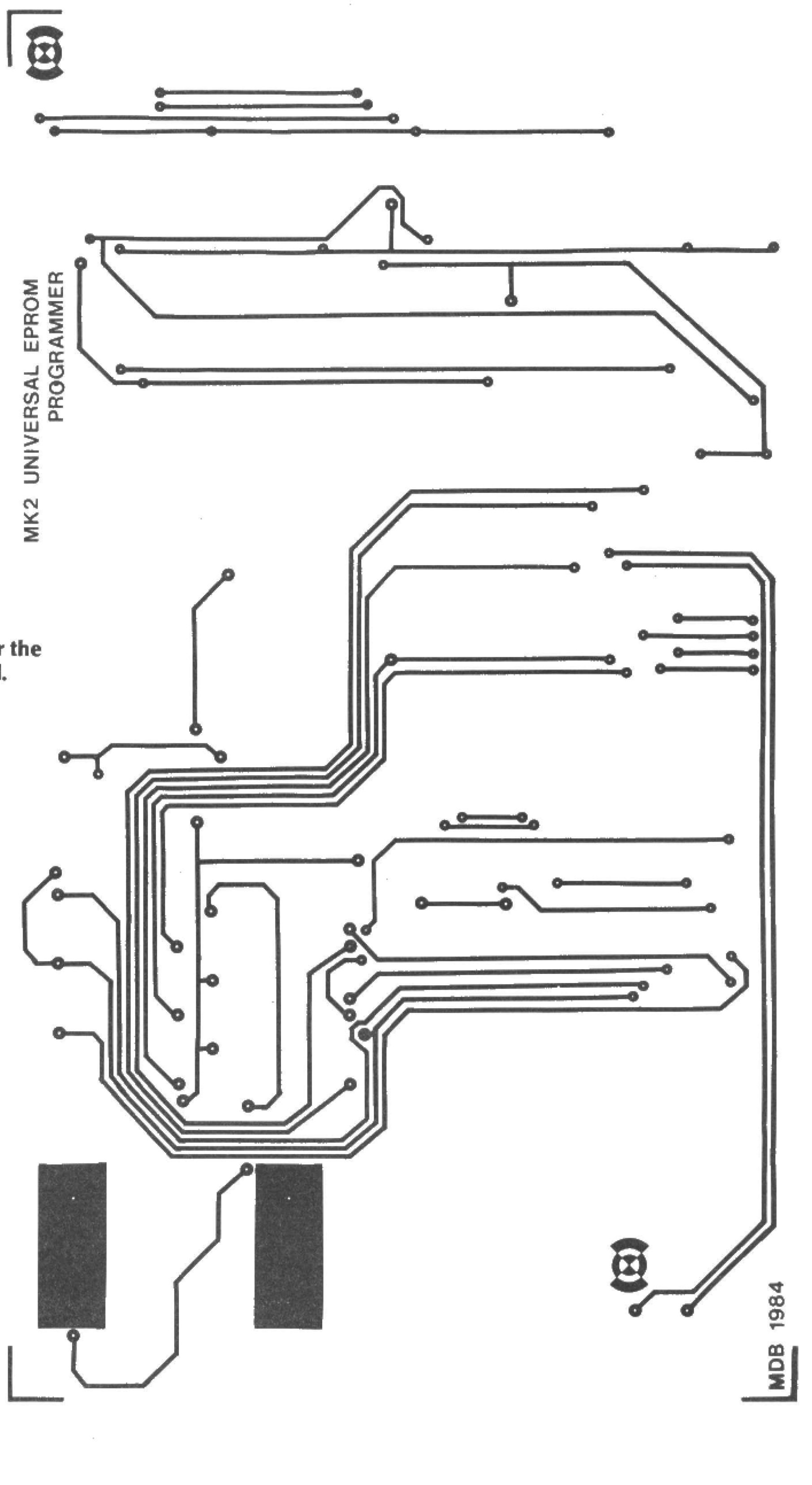
The optional tone control board for the audio mixer.



The top and bottom foils for the Electron Second Processor board.







The top and bottom foils for the EPROM Programmer board.

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ETI PCB SERVICE

In order to ensure that you get the correct board, you must quote the reference code when ordering. The code can also be used to identify the year and month in which a particular project appeared: the first two numbers are the year, the third and fourth are the month and the number after the hyphen indicates the particular project.

Note that these are all the boards that are available — if it isn't listed, we don't have it.

Our terms are strictly cash with order — we do not accept official orders. However, we can provide a pro-forma invoice for you to raise a cheque against, but we must stress that the goods will not be dispatched until after we receive payment.

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☐ E/8301-3 Programmable PSU 3.45
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☐ E/8303-2 Alarm Module 3.62
☐ E/8303-3 ZX81 User Graphics 1.07
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☐ E/8304-5 Stage Lighting — Display 3.45
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☐ E/8305-6 Stage Lighting Autofade .. 6.19
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☐ E/8306-5 Atom Keypad 5.18
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☐ E/8308-3 Universal EPROM prog ... 9.64
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☐ E/8311-1 Mini Drum Synth 3.07
☐ E/8311-2 Alarm Extender 3.21
☐ E/8311-3 Multiswitch 3.59
☐ E/8311-4 Multiple Port 4.34
☐ E/8311-5 DAC/ADC Filter 3.22
☐ E/8311-6 Light Pen 4.60
☐ E/8311-7 Logic Clip 2.51
☐ E/8311-8 MC Head (JLLH) 3.17
☐ E/8312-1 Lightsaver 1.85
☐ E/8312-2 A-to-D Board 12.83
☐ E/8312-3 Light Chaser (2 bds) 7.54
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☐ E/8411-6 Temperature Controller ... 2.88
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☐ E/8412-3 Active-8: Motherboard ... 9.37
☐ E/8412-4 Active-8: Protection Unit 3.67
☐ E/8412-5 Active-8: Crossover 3.67
☐ E/8412-6 Active-8: LF EQ 3.67
☐ E/8412-7 Active-8: Equaliser 3.67
☐ E/8412-8 Active-8: Delay Unit 3.67

1985

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☐ E/8506-2 Audio mixer PSU bd 3.87
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REVIEWS

GATE ARRAYS: DESIGN AND APPLICATIONS

Book
John Reed (ed)

Collins Professional and Technical Publishers
8 Grafton Street
London W1

price: £20

This book is divided into nine sections, written by different authors from different companies on (presumably) their specialities. The first section, which lays out the background information and the basic technology, is written by the editor.

Gate Arrays are, typically, ICs with the interconnections between different parts not defined. A customer requiring a specific logic function can specify the interconnection pattern to meet his requirements, and thus can have a "semi custom IC" without having to start from scratch, with all the cost that entails. Even the provision of interconnect masks its not a cheap or simple business, however, so this technology is not for prototyping purposes.

Details of the device technology are provided, both for bipolar and MOS arrays. Analogue/linear arrays are also available (not a lot of people know that) and both bipolar and CMOS versions are discussed. Digital gate arrays are often known as uncommitted logic arrays, or ULAs.

Manufacturing a gate array is a complicated procedure in which a mis-step can be very costly, and computer aided design (CAD) is a big help. About forty pages are devoted to this important topic. Following this is a short section on manufacturing, in which the author comments 'whereas full custom circuits can frequently take up to a full year to implement, gate arrays. . . can be produced in as little as three weeks from the time a logic diagram is received.' This cannot be cheap!

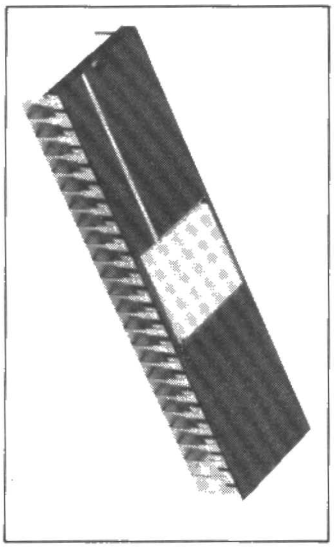
Once the design has been produced it must be tested. This is not as easy as it sounds, because it is not possible to place a logic probe at any convenient point in a complicated circuit. As the section covering this aspect points out, the design must be carried out so that the functioning of the circuit can be determined by access to the pins, and without having to take the circuit through every conceivable logic state.

After this are three sections on designing with and applying gate arrays. One example shown here is the Acorn Electron, in which most logic not connected with the microprocessor is carried out by a gate array. This includes video handling, sound generation and the cassette interface.

The book is primarily addressed to engineers and engineering management who are contemplating the use of gate arrays in their products. It deals with commercial and practical aspects as well as the technology, and rightly so in my view because many potential users of gate arrays must have no idea where the pitfalls lie. Given the rate of technological change, this book cannot give all the answers, but it pinpoints a lot of the important considerations in implementing a design in gate array form.

The electronics student is also liable to find this book useful, not least for the background information provided about semiconductor technology and devices. The home constructor will find little of relevance here, but those who are interested for interest's stake should give this informative book a look.

Andrew Armstrong



Received this month:

Microelectronics Systems 1 Checkbook
Microelectronics Systems 2 Checkbook
Microelectronics Systems 3 Checkbook
(R.E. Vears, Butterworths, London).

O-level and CSE Pass-cards, Electronics
(P. Clothier BSc, Letts, London)

LISP — The Language of Artificial Intelligence
(A.A. Berk, Collins, London)

These books will be reviewed next month.

Also next month, we will be reviewing the Microprofessor MPF 1/88 — an 8088-based development and training system from Flight Electronics, Southampton, and the Touchtech touch screen add-on for Microvitec monitors from Microvitec, Bradford.

DESIGNING MICRO PROCESSOR-BASED CIRCUITRY

Book

S.J. Cahill
Prentice-Hall International
66 Wood Lane End
Hemel Hempstead
Herts HP2 4RG

price: £9.95

Titling a book 'Designing Microprocessor-Based Digital Circuitry' is asking for trouble. Especially when the book in question carries a low price tag and is only a couple of hundred pages long. Dangerously so when the blurb claims that the book 'strips away the mystery surrounding microprocessors' and that it requires 'no prior knowledge of digital electronics and can be read by anyone with an appreciation of scientific method.'

The author, S. J. Cahill, works for the Department of Electronic and Electrical Engineering at the University of Ulster — pointedly described as being situated in 'N. Ireland, UK'. His own preface gives the lie to the blurb. The 'objective' of the book, he writes, is 'to strip off the mystery surrounding microprocessors as a digital device.' 'No great prior knowledge of electronics (is) assumed,' writes Cahill, and 'anyone with an appreciation of scientific method will benefit from the text.' The differences may be small but they are significant. The lesson we can learn is never to trust blurb-writers (or, for that matter, publishers).

That said, the text proper begins with a somewhat doubtful proposition. 'Electronics is defined as the art of processing information by electrical means,' writes the author. One wants to ask him, by whom is it so defined and what does it mean? Cahill has fallen into a trap before taking barely a step.

He has defined the subject of his study in order to fit the book, rather than writing a book which addresses the very real issues of how best to approach and understand microprocessor - based systems. This becomes clear as you move through the book, proceeding from an introduction to logic and digital circuits to a look at microprocesors finishing with the meat of the work — a project to build a 6802 controlled greenhouse thermometer.

This project forms well over half the book and ideas behind it are introduced as early as the first page of the text proper. My first question was, why build this particular project? This is a question that recurs throughout electronics and it's a question which Cahill makes some attempt to answer with, in my opinion, little success. My next question concerned Cahill's tendency to gloss over things that bear too little on the impending project. The book presumes a great deal and treats rather cursorily those aspects of electronics in general — and digital electronics in particular — which don't come within the author's purview.

There can be no doubt that the task Cahill has set himself is difficult. If he doesn't succeed gloriously he can be consoled by the fact that he has made a valiant attempt to take the ground. This is more than most writers on electronics ever do. Given its limitations, the book is well executed, readable and, at times, informative. Naturally, the project itself is handled with unimpeachable comprehensiveness. If you work through the book and construct the project (as suggested, on breadboard) there can be no doubt that you will end up with as good a working knowledge of 6802 MPU as can be had. This would be no small achievement, and no small return on the cost of the book. You would also be in a good position to develop a more general understanding of digital systems and microprocessors than could be guaranteed by any number of introductory texts. In that sense, Cahill's practical approach works — even if it doesn't quite attain his own or the blurb-writer's goal.

Gary Herman

TRAINS OF THOUGHT

Only three years ago if you said 'transistor' to the average railway modeller, he (or, rarely, she) paled visibly. If you said 'integrated circuit' he winced. And if you said 'computer' . . . well, you didn't because before you got that far he would have bolted from the room in blind panic.

A shame really, because the average railway modeller has quite an appreciation of electricity, of logic and of control. It's just that he is what he is because he likes to see things *move*. He's happy with switches by the bank, relays by the ream and rheostats by the kilowatt. But the the thought of electrons doing their thing out of sight inside black plastic cases where he can't get at them, well, that's contrary to all his instincts.

That was three years ago. Since then things have changed — and doubtless there are some who'll say, 'Not for the better'. Many railway modellers now are turning to electronics to solve some of their problems.

LEDs are now extensivley used as lamps (known, in the jargon, as *aspects)* in colour-light signals, an application for which they are far better suited than the traditional 'grain-of-wheat' bulbs. Train detection systems to tell the operator where his trains are — displaying the status, as like as not, on a mimic diagram — are no longer uncommon. And that's to say nothing of control systems of varying degress of sophistication, some of which generate simulated sound as well as giving the silkiest ever control of traction power.

Nor has the ubiquitous microcomputer left the railway modelling fraternity unscathed. Besides the miracles of four-bit processing that gave the world such command-control systems as Hornby's *Zero-1*, no exhibition railway layout is complete without a computerised display to tell the spectators what is supposed to be happening.

Many modellers have found their hands forced, if only because electronics offers the *only* feasible means to their end, the perfect reproduction in miniature of full-size railway practice. Readers of ETI, in contrast, need no convincing of the value of electronics. But you may perhaps be looking for some new avenue of application to challenge your expertise. If so, I urge you to consider railway modelling with an emphasis on such prototypical operations as multiple-aspect signalling and automatic train stop stems. In future issues I hope to give a selection of circuit ideas to show you some of the things that we modellers get up to in our lofts and attics and which I hope will set your trains of thought on the right lines!

Roger Amos

"AND FINALLY, I WISH TO PUBLICLY DENY ANY FINANCIAL INTERESTS IN FIRMS MANUFACTURING MICROPHONES AND STICKY TAPE!"

OPEN CHANNEL

British Telecom takes pride of place this month with several items of news, the first being the recent announcement that it intends to provide telephone services to passengers flying on British Airways' 747 Jumbo jets. It makes British Rail's plans for phones on Inter City trains look positively mundane, doesn't it?

In a joint venture with Racal Decca, BT is going to develop a 'flying phone' system in three distinct stages. The first of these will be a technical evaluation exercise which will determine the best aerials, methods, and communications technologies etc, to provide an acceptable service. One of the main determining factors is the requirement that aircraft communications must be within the UHF L-band of frequencies, from about 0.4 GHz to 1.5 GHz with wavelengths from about 77 cm to 19 cm.

The next stage is a marketing evaluation exercise, to find out just who is likely to want to use in-flight telephones. During this stage it is intended that, wait for it, calls will be free. (Hello operator. What do you mean, I can only make a local call?)

The final stage will be the implementation of a commercial service, which should be available by 1987.

When X Equals Y

On another front — good old-fashioned land based phones — BT appears less sure of itself and its directions. Recently, a spokesman for BT was reported to have confirmed that software problems bugging the development of System X exchanges have been ironed out. The very first BT operated System X exchange at Baynard House in the City of London should, by the time you read this column, be in service. By the end of June, it is planned that 15 such exchanges will be operational in the UK network.

It would appear that all things are hunky dory for the contracted manufacturers of System X exchanges, and that profits must now at least show on their order books. However, the same manufacturers must be feeling somewhat peeved by the even more recent announcements that BT is reported to have asked for tenders for the manufacture of System Y exchanges — to operate alongside their System X counterparts. The System X makers must surely feel that several years' worth of design, development and manufacture of System X exchanges has been overridden by BT's apparent lack of commitment.

Satellite TV

The direct broadcast by satellite (DBS) debate seems to be reaching a head, with the 'Club of 21' (the consortium which is to operate Britain's DBS television service) baulking at the costs of the proposed satellite rentals.

Unisat, the satellite organisation comprising British Aerospace, GEC and — yes, you've guessed it — British Telecom, whose satellites the DBS organisation are presently bound to use, has priced the use of satellites too highly according to the Club of 21. Britsat, another satellite organisation, has offered satellite rentals to the Club of 21 at a much lower cost, for a longer time, and it promises services sooner.

The debate is compounded by news that foreign manufacturers are soon to produce cheap DBS television receivers. As one of the primary aims of DBS in the UK is to allow British companies to make DBS TVs for our own market, it stands to reason that plans for DBS services must soon be finalised so that they may do just that — before foreign competition does the job for them.

The Club of 21 is now playing a waiting game. They believe they can force the government's hand to allow a free choice of satellite rental services, thus providing a more economical solution. Unisat is also playing a waiting game — it believes Britsat's service is inferior.

It has not been, however, the government's general policy to wait in the sidelines for arguments to sort themselves out, and there is little likelihood it will do so now, in the light of the foreign competition. So, there really are only two routes it can take. One, it may allow the Club of 21 to choose its own satellite supplier, or two, it may disband the Club of 21 and create an alternative, contractually obliged to accept Unisat's services.

With the government's reputation on negotiating settlements agreeable to all sides (almost non-existent), I would advise the Club of 21 to seriously consider its stance.

Keith Brindley

Trains of Thought and Open Channel welcome letters and information on products and events to do with modelling and telecommunications respectively. Please address correspondence to the relevant column at ETI, ASP Ltd., 1 Golden Square, London W1R 3AB.

SCRATCH PAD

by Flea-Byte

Now that STC have taken over ICL, poor old Robb Wilmot can't have much to do to fill his time. So, it's hardly surprising that the former ICL technical supremo has accepted a posting with Sir Clive Sinclair, the leading edge of the new technology. Wilmot will be looking after a new division of the Sinclair empire, formed to develop wafer-scale integrated circuits. Wafer-scale integration (WSI) means using a single wafer — or slice of silicon crystal (the biggest of which are 6 inches in diameter) to hold one enormously complicated circuit. The benefits in speed and energy consumption, when compared to circuits which have to wire up several chips, are obvious. So much so that two or three years ago, Gene Amdahl — former IBM whizz-kid and founder of Amdahl Computers — started up his Trilogy Corporation with the backing of six or seven of the world's leading computer manufacturers in an attempt to design and build a new computer based on WSI techniques. Some months, and many millions of dollars, later Amdahl gave up. The world, it would appear, was not ready for single circuits on a wafer — although it might be eager for a piece of cheese on a Ritz cracker. Sir Clive and his new partner Robb 'One Per Desk' Wilmot are not deterred. They have some money and they're going to spend it. Maybe all those customer complaints have finally got through to Sinclair. Since the object of WSI is faster processing time with a lower overhead, perhaps Sir Clive is thinking of a wafer scale circuit with a 28-day clock cycle (or your money back).

* * *

Another intriguing new hiring came to my attention recently. It seems that Robert Moog is now working for Kurzweil Music. Moog, you will recall, is the man who invented the synthesizer. Or, to be more precise, he realised that silicon components could be used to make flexible and virtually noise-free voltage controlled circuits which could then be patched together to produce complex waveform generating and wave shaping devices. Moog went on to design many of the now classic VCO, VCA and VCF circuits. He bundled several of them together with a piano-type keyboard and produced one of the very first analogue synthesizers. That was in the mid-sixties and, although he was once on the verge of joining the ranks of Biro, Hoover and Diesel — whose names have entered the language — his career took a nose-dive after reaching this peak. His company was bought out and, in his own words, Moog spent his remaining time there as 'window dressing'. Now he's moved across to join Ray Kurzweil, whose own career has been somewhat checkered. Kurzwell first came to public attention as the man behind optical character readers (OCRs) which can read text aloud, learn new typefaces and scan text for direct entry into databases. The company that produced the OCRs, Kurzweil Computer, was taken over by Xerox in 1980. It is said that Xerox were convinced by the Kurzweil charm that OCRs were about to become as common as photocopiers. It is also said that Xerox have been surprised to discover that this wasn't the case. Kurzweil himself made $6 million from the deal and went on to set up Kurzweil Music and produce the Kurzweil 250 — an electronic keyboard specifically designed to reproduce the complex tones of a grand piano as accurately as possible. The 250 does more than that, of course. At $11,000 a machine, it would have to. Kurzweil is very cagey about the technology used, revealing only that the 250 uses a combination of digital sound sampling and ROM-based algorithms. In order to distinguish the 250 from Fairlights, Synchlaviers, Emulators and other instruments, Kurzweil describes his technique as 'sound modelling'. The role that Moog played in developing the keyboard seems to have been minimal. According to Kurzweil, his major contribution was 'to settle our endless debates about whether we had got a sound right'. Moog himself says that 'the Kurzweil people understand my capabilites and are using them'. I don't know whether the Kurzweil 250 sounds like a grand piano or not, but I do know that it sounds like a hype.

* * *

Good news for those of you who can't afford a Sinclair C5. Designer Felice Campopiano has gone one better than the electric trike and produced an electric bike. The Pedelec's development has been funded by the Greater London Enterprise Board (to the tune of £76,000) and by Campopiano himself (£20,000). It will sell for £325 and have a maximum speed of 16 km/hr. We await with mounting excitement the announcement of an electric pedestrian.

* * *

Talking of which, more news from the Japanese robot front. The crafty blighters have produced a robot tea-lady which (who?) stops passers-by in their tracks by whispering — seductively, no doubt — 'I'm a vending robot, a tea sales girl. Let's talk.' Readers might like to submit the text of an ensuing conversation. I should point out, however, that ETI is staffed by editing robots and I am a writing robot. We're not noted for our sense of humour, but I'm sure if any of you succeed in making us laugh, I might persuade the subscription robots to send out a free subscription or a binder.

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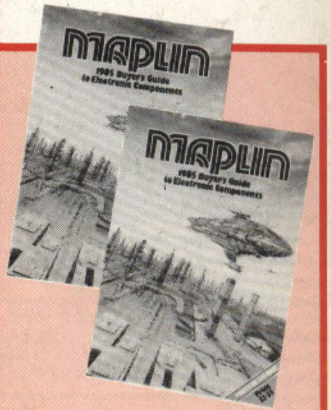

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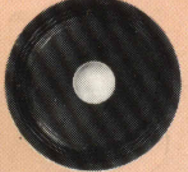

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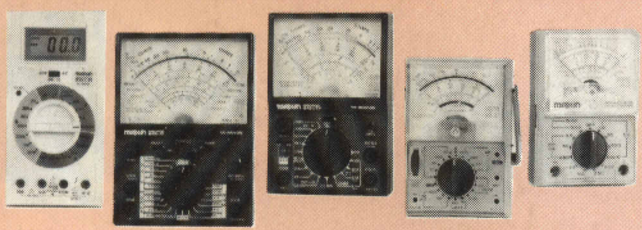

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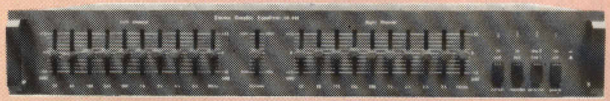

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